MICROCOPY CHART

EFFECT OF CHANGING DEPOT ON-TIME STANDARDS

DEPARTMENT OF DEFENSE

DEFENSE LOGISTICS AGENCY

Operations Research and Economic Analysis Office

Cameron Station,
Alexandria, Virginia 22304-6100

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DEPOT ON-TIME STANDARDS

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DEFENSE LOGISTICS AGENCY

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DLA-LO

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FOREWORD

This report summarizes the work done and conclusions reached in a
study of alternative depot time standards for routine requisitions.
The analysis was performed by the Operations Research and Economic
Analysis Management Support Office for the Directorate of Supply
Operations, Transportation Division.

DLA has been considering changing the current fifteen day depot time
standard for CONUS delivery of requisitions in Issue Priority Group
Three (IPG 3), for the purpose of improving the cost effectiveness of
DLA depots. The analysis quantified the estimated transportation
costs and other measures of comparison for all time standards from 15
to 21 days. Changing the time standard to 21 days would save
approximately five million dollars annually in transportation charges
alone, without significantly impairing the mission of responding to
military customers.
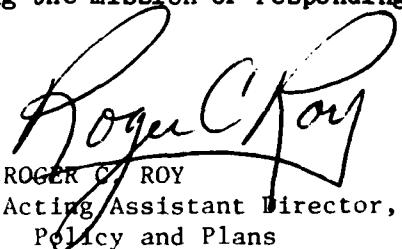
ROGER C. ROY
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EXECUTIVE SUMMARY

The Problem

The Defense Logistics Agency is considering extending its "on-time" standard for depot handling and delivery of supplies for routine requisitions from military customers. Regulations require delivery within 21 days after a requisition is received by a DLA depot, but DLA policy insures that over 90% of all such requisitions are delivered by only 15 days. By limiting the duration of shipping cycles, this policy may cause excessive transportation charges or other inefficiencies at depots without significant advantages to customers. A longer time standard such as 18 or 21 days may be beneficial, but the actual consequences need to be quantified.

The Approach

The analysis consisted of estimating several measures of comparison for the baseline (15-day) and alternative time standards. The primary measures were transportation charges, numbers of shipments according to type, numbers of shipping units, and on-time performance. Each time standard was evaluated for all six DLA depots separately.

The materiel analyzed in each case represented requisitions in Issue Priority Group Three (IPG 3) from military customers in the continental United States. Records of supplies delivered by DLA from January 1985 to June 1985 by truckload, less-than-truckload, United Parcel Service, or Fourth Class mail provided the necessary requisition history data.

A simulation model of relevant depot processes used the requisition data from a given depot to estimate the desired output measures based on the value of the time standard inputs. Simulation results were generated for time standards of 15, 18, and 21 days. Analytic formulas were derived to estimate the costs and numbers of shipments for additional time standards ranging from 12 to 24 days.

Results

The analysis concluded that extending the depot "bank" times, during which materiel to be shipped is consolidated, by increasing the time standard would significantly increase depot efficiency.

An IPG 3 time standard of 21 days would save over five million dollars per year, or about 15%, in transportation charges alone. Additional benefits include 27% reductions in numbers of shipments and 18% reductions in numbers of shipping units. Furthermore, on-time performance would probably improve, and the average customer pipeline time would increase by less than three days.

I. INTRODUCTION

A. Background

The Defense Logistics Agency (DLA) has traditionally measured the performance of its six depots by monitoring the separate processing, transportation hold, and intransit segments of operations for compliance with distinct time standards for each. Recently, however, DLA improved its service and efficiency by merging the three time segments into one with the aid of computerized workload planning. The greatest benefits were found in the processing of shipments for Issue Priority Group Three (IPG 3) requisitions, or Materiel Release Orders (MROs), the routine category of materiel constituting a majority of peacetime shipments. The time standard for this combined segment for IPG 3 requisitions was set at 15 days instead of the 21 days authorized by the Uniform Materiel Movement and Issue Priority System (UMMIPS). The resulting measure, "Depot Transportation On-Time Performance," is the percentage of MROs (requisitions, or lines) processed and transported within the DLA time standard.

The DLA goal for depot on-time performance has been set at 90% for several years, and all six depots are now meeting or exceeding this goal based on the 15-day standard. Performance above 90% appears to be a by-product of a "worst case" approach to meeting the goal. That is, MRO processing is designed to give the oldest MROs at a depot for a given set of customers at least a 90% on-time probability; hence the performance for newer MROs shipped with them is much higher. This behavior combined with the 15-day time standard and the 90% goal may be causing unnecessary inefficiencies, in terms of transportation charges and depot productivity, for a marginal gain in service to the customer. This is especially true if customers do not desire receipt of IPG 3 supplies before 21 days.

For example, many shipments must leave the depot eight or more days before due date in order to reach a cross-country customer on time. These supplies typically cannot be held at the depot long enough to combine with materiel intended for the same customer on subsequent days, missing the opportunity to combine into larger shipments at lower transportation rates. Similarly, additional processing must often be done when such consolidation is missed, because the numbers of shipping units and shipments are not minimized. The shipping cycle is longer for nearer customers, and some customers currently receive enough material to use low rates, but more consolidation could probably still be achieved with a longer time standard.

Alternative time standards closer to 21 days have been proposed, but the potential increase in consolidation, and the resulting benefits and costs, have not been quantified and analyzed in detail.

B. _Objectives_. The purpose of this study was to quantify the primary benefits and costs of alternative DLA time standards for IPG 3 shipments, and provide general insights about the causes and results of consolidation.

C. Scope

The analysis investigated time standards ranging from 12 to 24 days, but focused primarily on the 15-day, 18-day, and 21-day standards.

The materiel analyzed in each case included all IPG 3 requisitions from military customers in the continental United States (CONUS) which were delivered by one of the six DLA depots in a six month period by truckload (TL) or less-than-truckload (LTL) freight modes or by mail (UPS - United Parcel Service, or USPS - United States Postal Service). Annual results were estimated by extrapolation.

D. Overview. This report serves two purposes. First, it documents the methodology developed, for inspection and possible use by analysts. Chapters II, III, IV and VI and the appendices perform this function. Second and more importantly, it reports the insights gained from the analysis for use by decision makers. These are summarized in Chapter VII, based on results reported in Chapter V and Section E at the end of Chapter VI.

II. METHODOLOGY OVERVIEW

The study approach consisted of selecting appropriate analysis scenarios, defining useful measures of comparison, and designing and performing an analysis experiment to estimate the measures to compare alternative scenarios.

A. Scenarios

Three primary scenarios were chosen for comparison: the 15-Day Time Standard, the 18-Day Standard, and the 21-Day Standard. Six cases, one for each depot, were analyzed for each primary scenario. The depots are:

1. Defense Depot Mechanicsburg, Pennsylvania (DDMP)

2. Defense Depot Memphis, Tennessee (DDMT)

3. Defense Depot Ogden, Utah (DDOU)

4. Defense Depot Tracy, California (DDTC)

5. Defense Construction Supply Center (DCSC), Columbus, OH

6. Defense General Supply Center (DGSC), Richmond, VA

Less detailed results for time standards of 12 to 24 days are estimated from the 18 primary cases. A detailed description of the baseline (15-day) and alternative scenarios is presented later.

B. Measures of Comparison

The information needed to evaluate time standard alternatives included the following measures for each scenario:

1. Total transportation charges for each depot and all depots combined.

2. Total shipments from each depot, by each mode of transportation: TL, LTL or UPS/USPS.

3. Total shipping units from each depot, by warehouse type (Bir or Bulk) and transit type (freight or mail).

4. On-time performance (percentage of lines on-time to customer' for each depot.

5. Average transit time per shipment for each depot.

6. Total bank cycles and average bank time for each depot by distribution area.

It would also be useful to know in detail how processing operations vary from scenario to scenario, in terms of saturation levels and delays at different stages of processing, as well as administrative and personnel costs. The analysis did not explicitly quantify those measures, but the measures which were provided were expected to be useful inputs for understanding in such areas.

C. The Analysis Experiment

Given the defined scenarios and measures of comparison, the analysis performed the following steps:

1. Data Development. Sufficient data were selected to characterize the distribution of customer requisitions, transportation costs and transit times for each depot. Other information was obtained to describe the MRO process at each depot.

2. Methodology Development. The primary analysis tool was a detailed simulation model of the depot MRO process. For comparison sake, some independent analytic modeling was performed using probability assumptions.

3. Generation of Results. Simulation runs estimated the measures of comparison for the 18 input cases. Then the analytic methodology was calibrated to the simulation output to provide output estimates for a wider range of time standard alternatives.

4. Interpretation of Results. Insights gained from the results or during the analysis process were formulated as conclusions or recommendations.

Some steps were done concurrently, and several were iterated when necessary to satisfy the study objectives.

III. DATA DEVELOPMENT

The analysis methodology required three types of data about the system being modeled: MRO data, transportation charges, and transit times.

A. Depot MRO History Records

DLA retains a computer record of every MRO successfully processed and delivered to a military customer. Each customer is identified by its own account number, the Department of Defense Activity Address Code (DODAAC), and by its installation number, the Destination Cross-Reference Code (DCR). Detailed inspection of the records pertinent to the analysis scenarios revealed many different types of MROs and substantial diversity among types. The requisitions differed greatly in volume, weight, item type, and frequency of demand; furthermore, over 2000 separate installations (DCRs) received materiel from each depot, with the total weight received by individual DCRs ranging from a few pounds to millions of pounds a year.

Materiel to be shipped is consolidated on a DCR basis, so the simulation results were expected to be sensitive to the volume and nature of each DCR's business. As a result, the task of characterizing DCRs and their MROs with probability distributions for modeling purposes posed uncertainty about the accuracy and confidence of model results. Therefore, actual MRO records from a six-month period were used as inputs to the simulation model. This use of historical data meant that the model would be in a sense deterministic, because one could not test its sensitivity to inputs by varying the distribution of MROs. On the other hand, the large number of MROs (an average of over 200,000 per depot) was expected to produce statistically stable results, and use of two quarters of data would remove some of the seasonality of the results. Use of the same data for a given depot's three cases is also a variance reduction technique useful for significant comparison of alternatives.

The inputs used by the simulation model required only a few of the data fields from each MRO record. The simulation language used, SLAM II, also required that the data be in strictly numeric form. Thus the computer program which selected the desired records also substituted unique numbers for each DCR and each DODAAC, replaced postal state abbreviations with numeric state codes, and unpacked the packed-decimal fields recording the weight, cube and MRO receipt date.

The program matched each MRO by NIIN (National Item Identification Number) to a separate stock number file to look up the corresponding special requirements code, cargo code, and hazardous storage compatibility code. The first two codes were transformed to numbers and appended to the input record for use in the model, along with the modified DODAAC, to determine the compatibility of MROs for shipping unit consolidation. The hazardous storage code was used to eliminate radioactive items from the input MROs.

Other conditions were required for an input MRO record to be selected. Specifically, the MRO records selected for analysis were those which showed:

1. IPG = 3. MROs from IPG 1 and IPG 2 were not used as inputs, but the lower priority of the selected MROs was considered when modeling warehouse processing times.

2. National State Code. The numeric or postal state code had to show that the requisitioning activity is located in the continental United States.

3. CONUS Parcel Post Zone: value 1-8. Required for computation of small parcel shipments, and a second check against overseas customers.

4. Nonzero Weight, Cube or Transportation Charges. An entity must have weight or volume to have meaning in the model, or cost to be useful in model validation. Because some MRO quantities are 'rolled up' to the lead MRO in a transportation unit, the weight and cube on a selected record may not always be attributable to the item (NIIN) on the record; however, the resulting compatibility codes are representative of the items accounting for the weight, and the other information is accurate.

5. Mode = A (Truckload), B (Less Than Truckload), G (Surface Parcel Post), or 5 (United Parcel Service). Materiel shipped by any other modes is rarely evaluated in IPG 3 on-time performance.

6. Geographic Area Code in range A – Z. Each depot can also assign codes in range 0 – 9, but appears to reserve these for unusual (e.g. – disposal shipments) or overseas shipments.

7. Matchable NIIN. Needed for consolidation criteria. Rare MROs show blanks or non-MOWASP items in this field.

8. Document Identifier Code not equal to 'A5J'. This value indicates a property disposal shipment.

9. Hazardous Storage Compatibilty Code not equal to 'A1'. Rare radioactive items are discarded from the analysis.

The magnitudes of the six input cases are shown in Table 3-1.

Table 3-1

INPUT CASE AGGREGATE STATISTICS

Depot	Number of Records	Number of DCRs*	Number of DODAACs	Total Weight Shipped
Mechanicsburg	221,636	5461	14,453	40,112,592
Tracy	213,110	4326	12,148	35,766,953
Columbus	144,779	3340	11,098	8,627,052
Memphis	402,951	6165	19,485	98,428,861
Richmond	277,482	5109	14,398	46,929,401
Ogden	214,107	3389	6,899	22,733,508
All Depots	1,474,065	6165**	19,485**	252,598,367

*   Includes single DODAACs at installations with no DCR.

**   Minimum, based on Memphis figures, in lieu of actual combined count.

B. Transportation Costs

Two cost-estimating methodologies were derived: one for freight modes A and B, and another for parcels modes G and 5.

Six recent quarters of shipping records in the Freight Information System (FINS) file provided the data used to estimate mode A and B charges. The average charge per pound was computed for nine weight classes for each depot and state (including D. C.). Only the first 80% of each weight class, e.g. - 500 to 900 pounds for the 500 to 999 class, was used because shipments in the heaviest 20% of the class might have been billed at a discount at a higher weight. In addition, the minimum charge was estimated for each depot and state by averaging the costs of shipments under 200 pounds. Scaling factors were derived to estimate rates for cases with missing or insignificant values.

The cost of mailing a parcel through fourth class USPS or UPS ground service was computed by encoding current published cost tables, based on the weight of the parcel and the parcel post zone. The lower of the two charges would be selected for a given parcel.

C. Transit Times

Transit time estimates were based on historical military supply and transportation evaluation procedure document (MILSTEP) TK4 shipping times for FY84. A TK4 time is the number of days from the departure of a truck from the depot until its arrival at final destination. The mean TK4 time was computed for mode B shipments from each depot to each state and was used as the mean for the model's mode B transit time distribution.

The mode A data were incomplete because full truckload shipments are rare compared to LTL shipments. Nevertheless, mode A average times were found

for enough depot-state pairs that a general linear relationship between mode A and mode B times was found, permitting an approximation of any mode A time given the corresponding mode B estimate. Mode A times averaged about two-thirds as long as mode B times.

TK4 data is only available for freight delivery, so different data were required for mail, modes G and 5. The only such data available were the MILSTEP takeup times from D6S documents. The D6S times are measured from the recorded date of shipment until the date the customer has the supplies in stock, which includes the transit time and a usually small but variable receipt and takeup processing time at the receiving installation. Extensive D6S data are available for mode B as well as mode G and 5, so a statistical relationship was sought between median D6S times for the two types. The times for modes G and 5 appeared to be slightly less than corresponding mode B times, but a high variance about this relationship made the approximation technique statistically insignificant. It was decided that substituting mode B estimates for mode G and 5 would be conservative but analytically simple, and reasonable enough to avoid biased comparisons of alternatives.

IV. SIMULATION MODEL

A. System Description: The MRO Process

The process of satisfying IPG 3 MRO demand differs from depot to depot because each depot processes a unique set of MROs and employs different resources to perform its mission. The number of supply warehouses and the physical layout of each depot is different, as is the degree of use of automated conveyors, forklifts, and various packing devices. Furthermore, the unique geographic relationship of each depot to its customers has led them to divide the country differently into distribution areas for planning, banking and transportation purposes.

Despite these differences, each depot behaves according to the uniform Mechanization Of Warehousing And Shipping Procedures (MOWASP). This set of regulations describes detailed policies and procedures for processing MROs the same way at all depots. Therefore, while the depots may employ different internal means for certain tasks, one can describe a general system which all six depots conform to.

DLA Supply Centers (DSCs) transmit military supply requests to depots as MROs, where each MRO represents some quantity of only one type of item. Each requisition is identified by the customer's activity address code (DODAAC), the corresponding installation's Destination Cross-Reference Code (DCR), and its geographic distribution area. The MROs are also distinguished by Issue Priority Group. Those MROs which are IPG 1 or IPG 2 are separated from the IPG 3 MROs because they have shorter delivery suspenses and will rarely combine with the latter for shipment.

Each IPG 3 MRO arriving at a depot is stored in a computer "bank" for its distribution area, where it is combined into a shipping unit with other MROs from the same DODAAC when certain compatibility criteria are met. An MRO is then identified by shipping unit number and its own line number for that shipping unit. When the oldest MROs in an area's bank must begin physical processing at a warehouse in order to reach the customer on time, some or all of the area's shipping units are "dropped" from the computer.

When a shipping unit drops from the bank, it queues for processing at the appropriate warehouse behind higher priority IPG 1 and IPG 2 MROs. The warehouse is allowed typically one to three days to "pick" the material on each line from its storage location, pack the lines together (in boxes or on pallets) as the shipping unit, and send it to the freight or small parcel terminal for shipping. If designated for freight, a shipping unit will be held at the terminal for consolidation with other units destined for the same DCR and loaded on a truck to leave on a predetermined day. The total time at the freight terminal is usually between 24 and 48 hours.

B. Modeling Approach

The similarity between analysis scenarios motivated development of a single general model of the depot "system". The model could represent a specific scenario when driven by the appropriate input MRO data set and two input parameters: one to identify the depot and another to set the time standard. Subroutines which computed bank times, transportation charges, and transit

times used the input parameters to index the appropriate data or logic for that case.

The model-building process was an iterative sequence of steps. First, the general form of the model was derived from study of MOWASP regulations, direct observation of depot operations and conferences with DLA supply and transportation personnel. Successive and increasingly detailed flow diagrams were created depicting the essential model elements, as detailed assumptions were made about the behavior of the system. When the behavior was specified in sufficient detail, the model was explicitly diagrammed using the network elements of SLAM II, which could be directly translated into computer code (Appendix A). Extensive use of FORTRAN subroutines (Appendix B), possible in combined network-discrete modeling with SLAM, was needed to depict the system in a manner permitting estimation of the desired measures of comparison. Once the model was encoded and debugged, output was generated to verify and validate the methodology.

C. Model Features and Assumptions

1. General Model Concept

The MRO process can be described as the flow of entities (lines or shipping units) through a network of queues, branching nodes, and service activities. This network consists of essentially four different processes: arrival, banking, processing and transportation. Each MRO passes sequentially through the four processes by itself or as part of a larger unit, or entity. In its simplest form, the model is depicted by the network in Figure 4-1.

Figure 4-1. FOUR PROCESSES IN SIMULATION MODEL
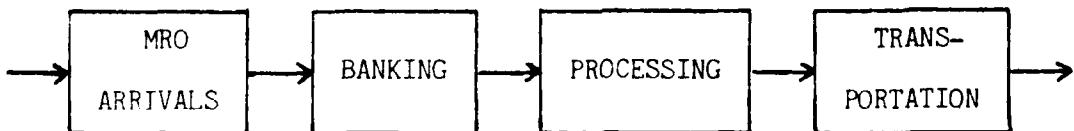
Events occur in each box which permit an entity to move to the next box and eventually leave the system. The assumptions made to fully describe the nature and timing of these events are described in the following sections, and are illustrated in the model flowchart in Figure 4-2.

2. MRO Arrivals

An entity is created each time an MRO record is read from the input file. Each entity arrives at a SLAM node which triggers two events. First, a subroutine is called to reference the current MRO record and assign the following attributes to the entity:

Figure 4-2.   GENERAL FLOW OF SIMULATION MODEL
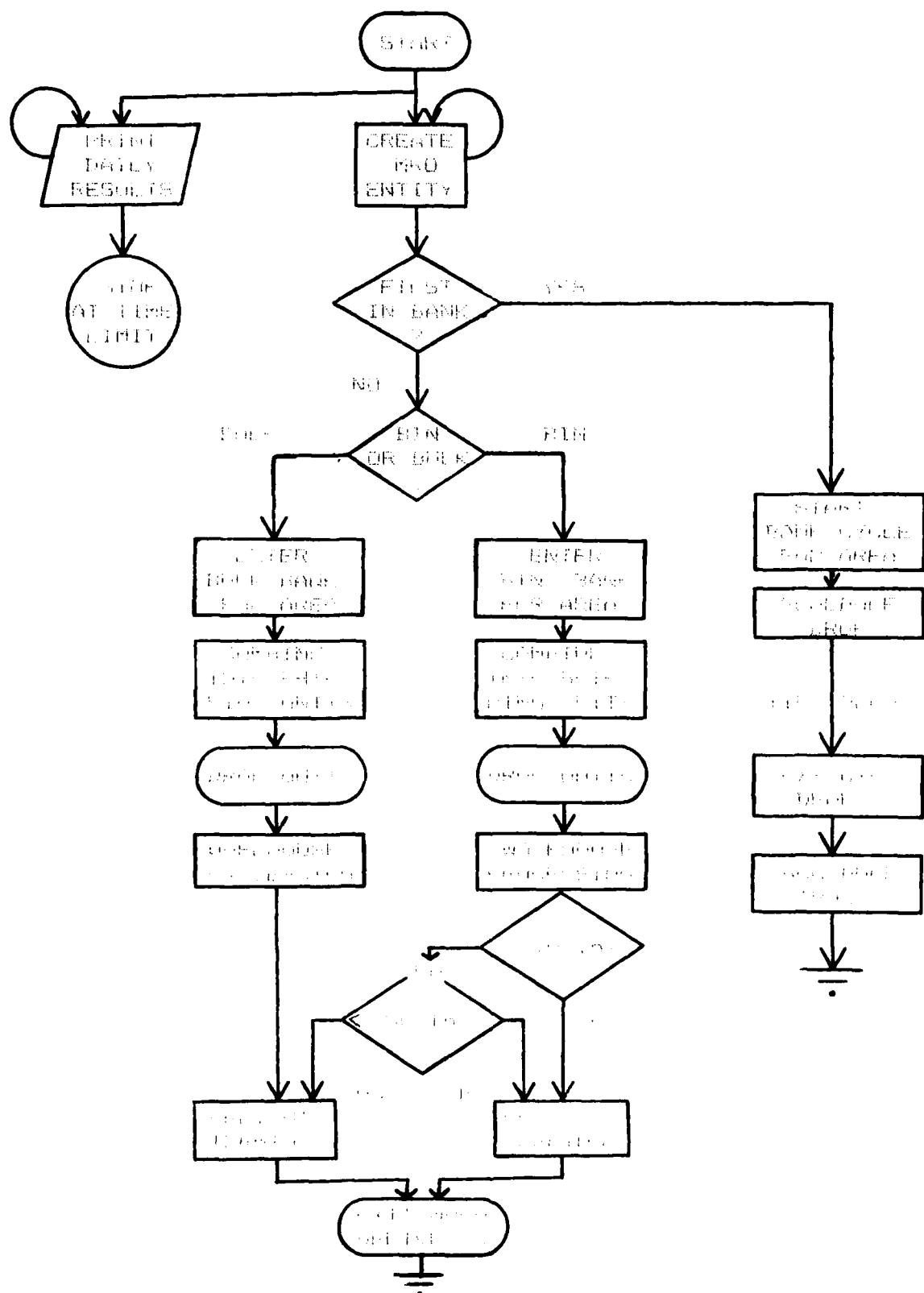
1: MARK TIME (Time in run when entity was created)
2: GEOGRAPHIC AREA CODE (Numeric, 1-25)
3: STATE CODE (Numeric)
4: DCR (Numeric Destination Cross-Reference Code)
5: SHIPPING UNIT TYPE (Based on DODAAC and compatibility codes)
6: PARCEL POST ZONE
7: WEIGHT (in pounds)
8: CUBE (in tenths of cubic feet)
9: BIN/BULK INDICATOR (1=Bin, 2=Bulk)
10: TIME TILL NEXT ARRIVAL (Zero or multiple of 24 hours)

Second, the same subroutine call reads another MRO record and stores the attributes for assignment to the next entity to arrive at the node. The difference in the two receipt dates (attribute 10) is used to schedule the next arrival. Thus, MRO entities arrive only at integer multiples of 24 hours: 0 (for the same day), 24, 48, etc. The first entity created also initiates the printing of daily processing results. The corresponding portion of the SLAM network is shown in Figure 4-3.

Figure 4-3.   SLAM NETWORK FOR MRO ARRIVAL PROCESS
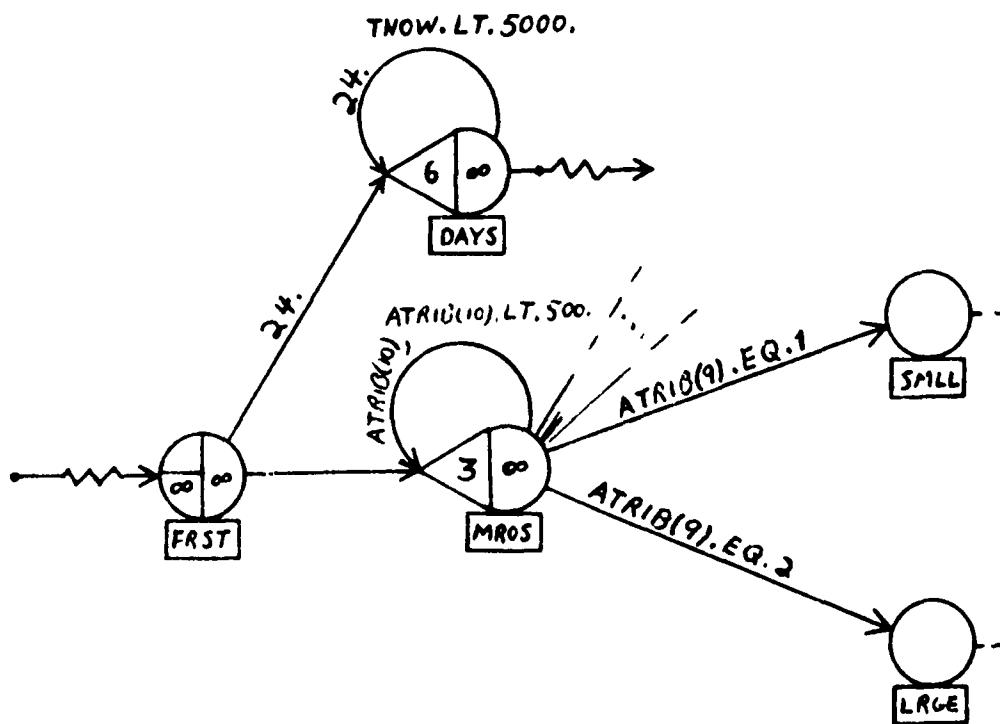
3. Bank Cycles

Each arriving MRO entity is routed immediately to one of two "bank" nodes for its geographic area, depending on the storage type (BIN or BULK) of the item on the MRO. The entity is stored in a file for its node until combined with homogeneous entities at that node into a shipping unit entity before the area's bank drops. The individual MRO entities are destroyed; the shipping unit entity retains their attributes as the following:

1: MARK TIME (Randomly chosen from MROs')
2: GEOGRAPHIC AREA CODE
3: STATE CODE
4: DCR
5: SHIPPING UNIT TYPE
6: PARCEL POST ZONE
7: WEIGHT
8: CUBE
9: NUMBER OF LINES (MROs) ON SHIPPING UNIT
10: FREIGHT INDEX (=1 if DCR will receive freight this cycle)
11: OLDEST MRO MARK TIME
12: NEWEST MRO MARK TIME

A subroutine call immediately prior to drop consolidates the MRO entities based on the value of attribute 5. The effect of this condition and the use of two nodes per area is that a given pair of MROs combine into a shipping unit if and only if:

a. The customer DODAACs match; and

b. Special Requirements Codes

1) are identical and not A (A's cannot combine), or

2) are both from the group H, J, 1, 9, and Z; and

c. Cargo Codes match and are H, Q, Z, or blank; and

d. Both are BIN or both are BULK.

The last condition assumes that stock is positioned at warehouses in such a way that two otherwise compatible MROs of the same approximate size (large or small) will not fail to combine due to stock locations.

All of the entities waiting at both nodes are dropped at the same time, which is actually two hours before the first planned processing day begins for the cycle, in order to exclude entities reaching the bank exactly when the day starts. The next MRO entity arriving after a drop has occurred begins a new drop cycle for that area. It becomes the first in the BIN or BULK node file for that area and its duplicate is routed independently to a "scheduling" network, where it calls a subroutine which schedules the next drop. The same entity goes on to trigger the drop at the scheduled time, call a subroutine to combine shipping units at the freight terminal into freight, and schedule the needed truck resource(s). The bank portion of the SLAM network appears in Figure 4-4.

Figure 4-4. SLAM NETWORK OF THE BANKING PROCESS

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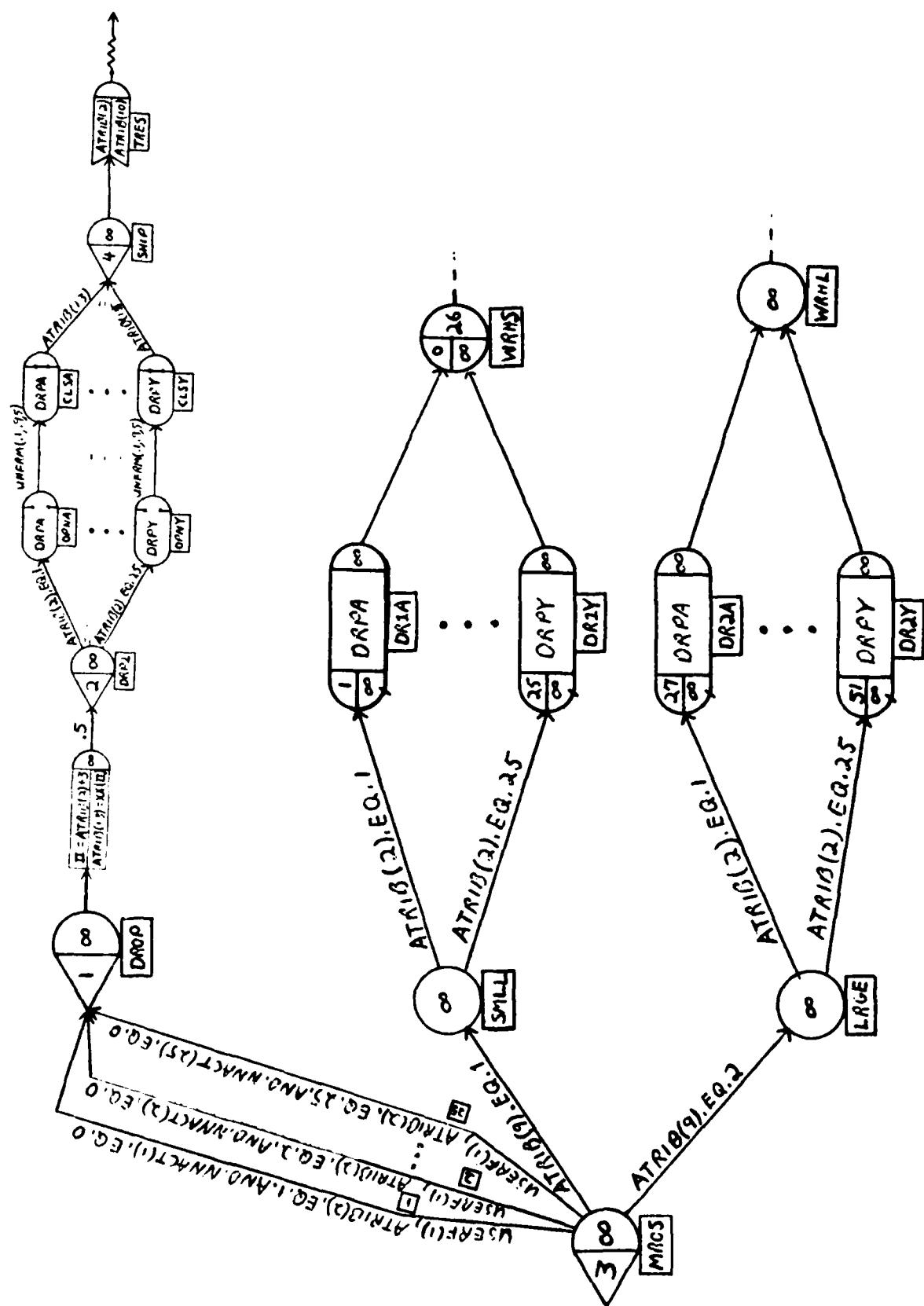
The duration of the bank cycle is based on the day of the week and the estimated shipping time for the distribution area. Statistics provided the highest integer number of days by which at least 90 percent of the mode B freight shipments to the area have been delivered. The model uses the depot and area to locate such a number in a data table and subtract it from the input time standard. The result gives the date by which the oldest MRO in the bank must be shipped (assuming mode B travel) to reach the customer with 90 percent reliability. Then three days processing and hold time are subtracted to yield the maximum bank time. The general model assumes that no processing occurs on Saturday or Sunday, so two additional days are subtracted if the three processing days intersect the weekend. If the resulting drop day is a Saturday, the MROs are dropped on Friday; if Sunday, they are dropped on Monday. If the computed bank time is less than one day, MROs drop within 24 hours after arrival.

A consequence of this banking methodology is that an area does not drop on the same day or days each week as is often done in reality. Rather than attempting to duplicate actual depot drop schedules, which would surely change for a different time standard, the model allowed an area's bank cycles to vary in timing and duration about the expected norm. The assumption of mode B travel times probably gives a lower average bank time in cases where the actual drop planners assume faster mode A travel, as does the absence of weekend processing days for some depots. On the other hand, three processing and hold days is less than some depots plan for, so the modeled bank time may be longer.

The workload timing constraints caused by IPG 1 and IPG 2 processing were not explicitly modeled, but the use of twenty-five distinct banks was assumed to produce a representative variability of daily IPG 3 processing. It was also felt that such "free-flow" cycle scheduling would provide useful insights about the timing of drops.

4. Shipping Unit Processing

The picking and packing operations at a depot are complex and labor-intensive, and differ greatly between depots and between warehouses at a depot. The details of warehousing were not critical to estimation of the analysis measures of comparison. The chief modeling needs in this area were to create an appropriate delay between the time a shipping unit drops for processing and the time it is shipped, and to route processed shipping units to the correct transportation terminal (freight or small parcel).

The processing time of a shipping unit is computed by a subroutine in the model as soon as the entity is dropped from the bank node. A random variate is drawn from a triangular distribution with a minimum time of 12 hours, a mode (and mean) time of 42 hours, and a maximum time of 72 hours. If the processing time intersects the weekend, a 48 hour delay is added. The shipping unit's processing time is assumed to be independent of the number of lines and the other shipping units being processed. The triangular distribution was conservatively estimated from the statistical

distribution of the difference between MRO drop dates and the dates offered to transportation, which were almost always two days or less. Perfect supply is assumed: any shipping unit dropped will be successfully picked, packed, and delivered to transportation.

Shipping units were sent to transportation terminals according to the size of the shipping unit and the total amount of materiel going to each DCR from the same bank cycle. Any shipping unit of ten pounds or less which did not exceed 3.5 cubic feet automatically went to the small parcel (UPS/USPS) terminal, while any shipping unit exceeding 50 pounds or 3.5 cubic feet went to the freight terminal. Any remaining entity (11 to 50 pounds, less than 3.5 cubic feet) went to the freight terminal if any single shipping unit to the same DCR qualified for freight. Otherwise, such units were sent by UPS or USPS. The freight eligibility had been indicated in an attribute on each shipping unit when created at the bank node, following inspection of all the MROs going to each DCR. Any shipping unit processed at the BULK warehouse went freight because any parcel post-eligible item (50 lbs. or less, 3.5 cubic feet or less) was defined as a BIN item on the input record.

    5. Transportation

Two transportation terminals were modeled: one for mail and another for freight. The SLAM network is shown in Figure 4-5.

        Figure 4-5. SLAM PROCESSING AND TRANSPORTATION NETWORK
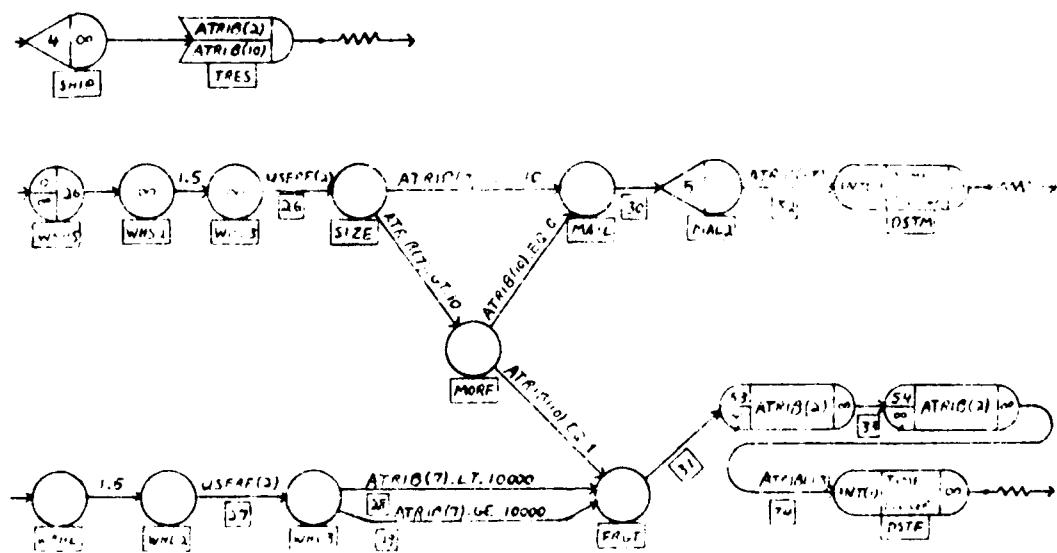
Shipping unit entities reaching the mail terminal become individual small parcel UPS or USPS shipments. Each calls a subroutine which computes the cost and transit time and updates the output statistics for the model run. The transit time is a triangularly distributed random variable for the state and depot, with endpoint parameters chosen such that about ten percent of the transit times exceed the planned transit time. The transit time found is added to the elapsed time in the system of one of the shipping unit's MROs, based on the value of attribute 1. This yields the total days from depot receipt until delivery to the customer.

Freight shipments are created through the interaction of several model elements. Shipping unit entities which have been processed and routed to the freight terminal are grouped by DCR at a freight node. There they wait until matched with an available SLAM "resource" corresponding to trucks.

The same scheduling network entity which initiated the bank cycle and the drop for a given area reaches a final event node three processing days after the drop is made. At that time a subroutine consolidates the area's shipping units at the freight node into shipments. Units destined for the same DCR combine into the minimum number of shipments possible such that the average shipment weight to the DCR is 40,000 pounds or less and the average volume is 1600 cubic feet or less. Charges are computed based on the total weight to the DCR. A shipment can be billed in a higher weight class if doing so reduces the total charges. A random variate is generated to compute the LTL mode B (less than 10,000 lbs.) transit time, which is scaled downward for a TL mode A (10,000 lbs. or more) shipments. A half day is added to the transit time to reflect additional hold time required to load the shipping units onto the truck. The total processing and hold time is therefore between 12 and 72 hours (not counting weekends) per shipping unit, because these shipping units had already been at the terminal for between zero and sixty hours (72 hours since the drop minus 12 to 72 hours processing time).

Although individual shipping units are destroyed when the shipment entities are created, their attributes are retained until after the shipment's transit time has been found. This permits on-time statistics to be computed for each shipment just as at the small parcel terminal node. After the consolidation has been done, the scheduling entity creates one truck resource unit for each newly created shipment entity. The resources are labelled by area, so that only the desired shipments are matched with the resources needed to leave the node.

D. Model Verification and Validation

Model debugging and verification required creation of a small (5000 records) data set to minimize program run times. The SLAM network was debugged to the point where an input case would run to completion. Then, additional runs were performed to verify that the program accurately executed the model's assumptions. SLAM event trace reports were inspected to determine if each node and subroutine performed as desired in the desired order.

When the code was verified as a correct representation of the model, larger data cases were run to validate the model. The same MRO data which was transformed for model inputs was used to recover the historical numbers of shipments and transportation costs by transit mode. Model results for the 15-day time standard were compared to the historical results. When the differences were attributable to specific modeling assumptions which could be easily improved, model refinements were made. Some differences were regarded as acceptable, because the simplifying assumptions causing them were not expected to bias the comparison of alternatives. A comparison of actual and model results is shown in Table 4-1.

Table 4-1

MODEL VALIDATION STATISTICS

	"Best" Match Columbus	"Worst" Match Richmond	All Depots Combined
% Weight Freight			
Actual	86.67%	94.65%	95.62%
Simulated	91.77%	98.68%	98.39%
% Weight Not Freight			
Actual	13.33%	5.35%	4.38%
Simulated	8.23%	1.32%	1.61%
Freight Shipments			
Actual	9,982	20,359	140,857
Simulated	9,470	16,288	100,630
UPS/USPS Shipments			
Actual	73,102	87,614	637,308
Simulated	56,083	66,592	411,468
Total Shipments			
Actual	83,044	108,973	778,165
Simulated	65,553	82,880	512,098
Transportation Charges			
Actual	$ .996M	$3.021M	$17.081M
Simulated	$1.027M	$2.516M	$15.711M

The comparison suggests that the model's level of consolidation may be an ideal which is difficult to achieve in practice, particularly in consolidation of small parcels into freight. Part of the difference may be due to the model's assumption that only shipping units weighing ten pounds or less will automatically travel by UPS or USPS. Actual depots may use higher weight thresholds, or may merely be imperfect consolidators.

Modeled bank times are another source of differences. For a number of reasons, the actual depots appeared to bank MROs for an average of about one day less than the model estimated. The depots each appeared to use longer transportation hold times than in the model, and the time difference was most pronounced for the depots matching the model results the least. Although transportation hold times contribute to consolidation, planning for extended hold times is suboptimal because it generally shortens bank times. It can be shown that this actually reduces consolidation because hold times do not combine materiel from subsequent cycles as effectively as extending the cycle with bank times.

DLA transportation officials and the depots know that unnecessary use of small parcel shipments and short bank times is inefficient, so they are continually striving to perform more optimally. Therefore, rather than alter the modeled threshold or design imperfections into the model, best-case estimates of depot performance were sought. This should insure that the benefits of increased time standards would not be overstated.

E. Output Generation

1. Outputs Provided. Each run of the model produced a variety of output. The categories of output were:

a. Shipping unit summaries by warehouse type and day of the week, including the total shipping units. The number completed, the number dropped and the number reaching each transportation terminal are given.

b. Drop cycle durations by customer area and all areas.

c. The total weight shipped by each mode of transit.

d. A transportation cost summary by mode and customer area.

e. The number of shipments by mode and customer area.

f. The average transit times by mode and customer area.

g. The distribution of the number of days for a shipping unit to reach the customer, by area and overall.

h. A day to day count of shipping units processed for each day of the model run.

Sample output from a single case is shown in Appendix C.

2. Primary Cases Run. Three time standard cases (15, 18, and 21 days) were run for each depot, for a total of 18 primary cases.

Some cases were run several times with alternate model versions to test the impacts of key input parameters such as the ten pound automatic mail threshold for shipping units and alternative algorithms for transit time, costing, and freight consolidation logic. The outputs tended to change slightly in magnitude, but not in a way which changed percentage differences between scenario costs or shipments.

V.   SIMULATION RESULTS

Simulation outputs were collected for all input scenarios and summarized for each measure of comparison. The results were estimates for only six months of depot operations.

A.   Transportation Charges

The total estimated transportation costs for the baseline (15-day) scenario at all six depots was $15.71 million for six months. This was reduced to $14.21 million for the combined 18-day standard, a savings of $1.5 million or 9.6 percent. The 21-day standard total cost was $13.36 million, a savings of $2.35 million or 15.0 percent over the baseline. The greatest percentage savings were estimated for the Mechanicsburg depot, saving 14.0 percent ($369 thousand) with a 18-day standard and 19.5 percent ($514 thousand) with a 21-day standard. The lowest percentage savings were 6.5 percent and 11.4 percent for the Richmond depot.

Complete results, including costs by mode of transit, are shown in Table 5-1.

B.   Total Shipments. The total number of shipments for all depots was 512,098 for the 15-day standard, 421,307 (17.7 percent less) for 18 days, and 374,108 (26.9 percent less) for 21 days. The reductions resulted from decreases in small parcel (UPS/USPS) shipments and mode B (LTL) shipments from each depot, while mode A (TL) shipments actually increased slightly. The shipment results are summarized in Table 5-2. The levels of consolidation are further illustrated by the weight shipped per mode of transit, shown in Table 5-3.

C.   Shipping Unit Summaries. The total number of shipping units also decreased as the time standard increased. From a baseline total of 745,200 shipping units, the 18-day number dropped 10.7 percent to 665,263, and the 21-day total dropped 17.7 percent to 613,040. More detailed results are shown in Table 5-4. The decreases were driven by 11.6 and 18.9 percent declines in bin item shipping units, and by 8.0 percent and 13.9 percent drops in bulk item units, although the number of lines of each type did not change. The number of shipping units delivered by UPS and USPS decreased by 16.3 percent and 25.2 percent in the 18-day and 21-day results. The number of shipping units delivered as freight decreased by only 3.9 percent and 8.5 percent, because much of the materiel previously shipped as small parcels became freight shipping units when the time standard increased.

D.   On-Time Performance

The on-time performance easily exceeded 90 percent in each simulation scenario. In fact, the average on-time performance per depot was 97.4 percent for the 15-day standard, 98.3 percent for the 18-day standard and 99.2 percent for the 21-day standard. Several scenarios showed the depot achieving the 90 percent goal a day or more early. The frequency of this observation increased whenever the time standard increased.

Table 5-1

SIMULATED IPG III TRANSPORTATION COSTS   SIX MONTHS

Depot	Scenario	Transportation Charges ($ Thousands)				Percent
		Truckload	LTL	UPS/USPS	Total	Decrease
Mech	15 days	608.49	1,823.61	197.45	2,629.55	0.00%
	18 days	668.11	1,442.29	150.39	2,260.79	14.02%
	21 days	697.80	1,287.36	130.47	2,115.63	19.54%
Tracy	15 days	618.36	1,321.34	181.91	2,121.60	0.00%
	18 days	674.62	1,110.05	149.78	1,934.45	8.82%
	21 days	692.86	980.59	132.65	1,806.10	14.87%
Colum	15 days	106.96	758.29	162.17	1,027.42	0.00%
	18 days	117.03	691.99	127.24	936.26	8.87%
	21 days	126.00	646.08	110.53	882.61	14.09%
Memp	15 days	2,508.08	2,341.47	279.68	5,129.23	0.00%
	18 days	2,581.70	1,866.68	221.63	4,670.01	8.83%
	21 days	2,605.45	1,637.94	194.19	4,437.57	13.48%
Rich	15 days	879.34	1,464.99	171.14	2,515.46	0.00%
	18 days	927.43	1,277.83	146.77	2,352.04	6.50%
	21 days	953.21	1,144.27	132.24	2,229.72	11.36%
Ogden	15 days	520.52	1,540.29	227.31	2,288.12	0.00%
	18 days	579.53	1,294.88	180.07	2,054.48	10.21%
	21 days	609.93	1,124.44	150.59	1,884.96	17.62%
Combined						
	15 days	5,241.75	9,249.99	1,219.66	15,711.37	0.00%
	18 days	5,548.42	7,683.72	975.88	14,208.02	9.57%
	21 days	5,685.25	6,820.68	850.67	13,356.59	14.99%

Table 5-2

SIMULATED IPG III SHIPMENT DISTRIBUTION BY MODE – SIX MONTHS

Depot	Scenario	Number of Shipments by Mode			Total	Percent Decrease
		TL	LTL	UPS/USPS		
Mech	15 days	1,160	21,325	72,303	94,788	0.00%
	18 days	1,255	14,119	57,752	73,126	22.85%
	21 days	1,302	11,805	51,559	64,666	31.78%
Tracy	15 days	1,165	11,257	54,772	67,194	0.00%
	18 days	1,248	8,678	46,794	56,720	15.59%
	21 days	1,277	7,237	41,951	50,465	24.99%
Colum	15 days	145	9,325	56,083	65,553	0.00%
	18 days	156	7,442	46,217	53,815	17.91%
	21 days	166	6,590	41,055	47,811	27.07%
Memp	15 days	3,238	23,023	93,206	119,467	0.00%
	18 days	3,281	16,329	77,940	97,550	18.35%
	21 days	3,261	13,867	69,770	86,898	27.26%
Rich	15 days	1,428	14,860	66,592	82,880	0.00%
	18 days	1,497	12,126	59,695	73,318	11.54%
	21 days	1,505	10,324	55,024	66,853	19.34%
Ogden	15 days	635	13,069	68,512	82,216	0.00%
	18 days	695	9,939	56,144	66,778	18.78%
	21 days	727	8,240	48,448	57,415	30.17%
Combined	15 days	7,771	92,859	411,468	512,098	0.00%
	18 days	8,132	68,633	344,542	421,307	17.73%
	21 days	8,238	58,063	307,807	374,108	26.95%

Table 5-3

IPG III WEIGHT SHIPPED BY MODE - SIX MONTHS SIMULATION

Depot	Scenario	Millions of Pounds Shipped by Mode			
		TL	LTL	UPS/USPS	Total
Mech	15 days	24.533	14.874	0.626	40.033
	18 days	26.698	12.872	0.467	40.033
	21 days	28.059	11.573	0.404	40.033
Tracy	15 days	23.737	11.047	0.508	35.292
	18 days	25.633	9.244	0.414	35.292
	21 days	27.160	7.773	0.359	35.292
Colum	15 days	2.365	5.326	0.691	8.382
	18 days	2.650	5.226	0.514	8.382
	21 days	2.884	5.060	0.445	8.382
Memp	15 days	78.183	19.061	1.020	98.264
	18 days	81.515	15.954	0.795	98.264
	21 days	83.469	14.109	0.686	98.264
Rich	15 days	32.370	13.859	0.618	46.846
	18 days	34.004	12.326	0.516	46.846
	21 days	35.293	11.098	0.454	46.846
Ogden	15 days	11.249	10.856	0.575	22.680
	18 days	12.738	9.494	0.448	22.680
	21 days	13.985	8.323	0.372	22.680
Combined					
	15 days	172.437	75.023	4.038	251.496
	18 days	183.238	65.116	3.154	251.496
	21 days	190.850	57.936	2.720	251.496

Table 5-4

SIMULATED IPG III SHIPPING UNITS - SIX MONTHS

Depot	Scenario	By Warehouse Type Bin	Bulk	By Transit Type Mail	Freight	Total	Percent Decrease
Mech	15 days	97,889	34,923	72,303	60,509	132,812	0.00%
	18 days	83,928	30,870	57,752	57,046	114,798	13.56%
	21 days	77,107	28,866	51,559	54,414	105,973	20.21%
Tracy	15 days	78,329	23,298	54,772	46,855	101,627	0.00%
	18 days	70,138	21,554	46,794	44,898	91,692	9.78%
	21 days	64,189	19,998	41,951	42,236	84,187	17.16%
Colum	15 days	72,108	11,995	56,083	28,020	84,103	0.00%
	18 days	62,837	11,119	46,217	27,739	73,956	12.06%
	21 days	57,463	10,564	41,055	26,972	68,027	19.11%
Memp	15 days	142,044	53,643	93,206	102,481	195,687	0.00%
	18 days	126,156	49,475	77,940	97,691	175,631	10.25%
	21 days	115,876	46,111	69,770	92,217	161,987	17.22%
Rich	15 days	89,014	29,696	66,592	52,118	118,710	0.00%
	18 days	82,237	28,093	59,695	50,635	110,330	11.94%
	21 days	76,984	26,552	55,024	48,512	103,536	12.78%
Ogden	15 days	89,286	22,975	68,512	43,749	112,261	0.00%
	18 days	77,502	21,354	56,144	42,712	98,856	11.94%
	21 days	69,392	19,938	48,448	40,882	89,330	20.43%
Combined							
	15 days	568,670	176,530	411,468	333,732	745,200	0.00%
	18 days	502,798	162,465	344,542	320,721	665,263	10.73%
	21 days	461,011	152,029	307,807	305,233	613,040	17.73%

Complete results, including the cumulative percentages of units delivered
three days, two days, and one day early, are shown in Table 5-5. For
example, in the Mechanicsburg 15-day scenario, 69.0 percent were delivered
by 12 days, 81.4 percent by 13 days, 90.3 percent by 14 days, and 95.5
percent by 15 days.

E. <u>Average Transit Times</u>. The average transit time per shipment
decreased slightly but consistently as the time standard increased, as
summarized in Table 5-6. The slightness of the differences between time
standards is explained by the fact that the random variable transit time's
mean value for a particular mode, depot, and destination state was constant
for all time standards, and by the fact that the high number of small
parcel shipments (roughly 80% of the total) dominated the computed average.
The decreases which did occur resulted primarily from the slight increases
in the fraction of total shipments which went by the fastest mode: full
truckloads. The high variance of each transit time reported should inhibit
drawing further conclusions from the transit time results.

Table 5-5

CUMULATIVE FRACTION DELIVERED BY DAY

Depot	Time Standard (TS)	TS-3	TS-2	TS-1	TS
Mechanicsburg	15	.690	.814	.903	.955
	18	.809	.894	.946	.978
	21	.874	.928	.964	.985
Tracy	15	.660	.854	.960	.992
	18	.802	.897	.951	.984
	21	.878	.940	.982	.998
Columbus	15	.652	.840	.946	.986
	18	.810	.903	.958	.985
	21	.862	.932	.976	.994
Memphis	15	.758	.858	.923	.962
	18	.838	.909	.955	.979
	21	.895	.943	.971	.987
Richmond	15	.666	.830	.934	.983
	18	.802	.900	.964	.993
	21	.870	.939	.981	.997
Ogden	15	.638	.795	.907	.965
	18	.795	.893	.952	.982
	21	.876	.937	.973	.991
TOTAL	15	.677	.832	.928	.974
	18	.809	.899	.954	.983
	21	.876	.937	.974	.992

Table 5-6

AVERAGE TRANSIT DAYS PER SHIPMENT

DEPOT	TS	TL	LTL	UPS/USPS	OVERALL
Mechanicsburg	15	3.99	6.59	6.50	6.49
	18	3.79	6.52	6.45	6.42
	21	3.86	6.57	6.41	6.39
Tracy	15	3.69	6.15	6.25	6.19
	18	3.60	6.14	6.24	6.17
	21	3.66	6.18	6.26	6.18
Columbus	15	3.76	6.19	6.16	6.16
	18	3.92	6.19	6.13	6.13
	21	3.83	6.23	6.12	6.13
Memphis	15	3.18	5.92	5.67	5.65
	18	3.17	5.74	5.54	5.49
	21	3.24	5.70	5.53	5.47
Richmond	15	3.33	5.85	5.36	5.41
	18	3.27	5.74	5.27	5.31
	21	3.33	5.80	5.24	5.29
Ogden	15	3.72	6.71	6.88	6.83
	18	3.66	6.63	6.78	6.72
	21	3.77	6.62	6.74	6.68
TOTAL	15	3.61	6.23	6.14	6.12
	18	3.57	6.16	6.07	6.04
	21	3.61	6.18	6.05	6.02

F. Bank Cycle Durations

The overall average number of days per bank cycle increased from 3.47 days for the 15-day standard to 6.75 days for the 18-day standard.   The corresponding total bank cycles for all bank areas numbered 6981 for a 15-day standard, dropping to 3576 bank cycles for 18 days and 2498 cycles for 21 days. More complete results are shown in Table 5-7.

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Table 5-7

AVERAGE DAYS PER BANK CYCLE

DEPOT	TS	Lowest Area Average	Highest Area Average	Average For All Areas	Total Cycles All Areas	% Drop In Number
Mechanicsburg	15	1.16	5.41	2.37	1318	0
	18	3.55	7.11	5.90	546	58.57
	21	6.96	10.73	8.47	385	70.79
Tracy	15	3.50	6.00	4.10	1126	0
	18	6.86	8.67	7.02	677	39.88
	21	9.80	12.50	10.14	470	58.26
Columbus	15	2.80	6.89	4.10	956	0
	18	6.86	9.00	7.38	543	43.20
	21	8.74	12.92	10.36	390	59.21
Memphis	15	1.17	7.00	3.15	1224	0
	18	3.53	8.77	6.65	589	51.88
	21	6.86	13.00	9.65	407	66.75
Richmond	15	1.73	7.00	4.18	1114	0
	18	5.24	9.75	7.38	629	43.54
	21	7.14	13.73	10.51	456	59.07
Ogden	15	1.17	7.00	2.89	1243	0
	18	3.52	10.00	6.17	592	52.37
	21	6.90	13.73	9.52	390	68.62
TOTAL	15	1.17	7.00	3.47	6981	0
	18	3.52	10.00	6.75	3576	48.78
	21	6.86	13.73	9.78	2498	64.22

G. **A Key Effect**. Two points explain the slight but consistent increases in on-time performance with longer time standards. First, the increased use of fast, reliable TL shipments virtually guarantees on-time delivery of some materiel which might be late under lower time standards. More significant is a subtle benefit of increased bank times. The average age of MROs in a bank is about one-half the bank time. As a result, increasing the time standard (and thus the average bank duration) by a certain amount increases the average age of dropped MROs by only one-half that amount. The additional timeliness cushion is carried on through the processing and transit operations. This speculation was confirmed by computation of median delivery times for the 18-day and 21-day time standards. The three additional bank days added from 1.04 to 1.61 days to the median delivery time. The overall average delay was only 1.38 days.

H. Remarks

Some of the preceding results should be used cautiously due to limiting
assumptions in the model. For example, the computed on-time performance is
undoubtedly high in each case because actual warehouses will occasionally
process an item too late for shipment in the intended cycle, but this was
not permitted in the model; furthermore, validation cases showed that
actual depots probably ship more by small parcels and less by faster TL
shipments than the model estimated.

Another example: the number of shipping units estimated in the model is an
ideal minimum, because bin item consolidation was not constrained by
warehouse location, and the same holds for bulk items. The assumptions are
consistent between scenarios, however, so the relative (percentage)
differences in shipping units may be meaningful even if the magnitudes are
conservative.

The bank time results are also probably high predictions of those
achievable in reality. Actual depots appear to hold items at the freight
terminal longer than the model assumes. This may be due in part to early
partial drops of an area's MROs needed to level daily processing workloads.
Again, the banking logic is ideal but consistent across all scenarios.

These examples merely confirm that the model's output is useful only if
interpreted in light of the model's assumptions. In general, the model
assumed that all depots performed near a theoretical optimal level of
efficiency for the particular time standard. The better a depot performs,
the less room it has for improvement; therefore, the model's estimated
benefits of increasing the time standard are probably conservative. In
other words, an estimated savings of $5 million is more likely to be low
than to be high.

The most reliable insights possible from the model are probably in the
effect that bank times have on both numbers of shipments and total
transportation charges. The relative reductions in numbers of cycles for
different scenarios closely parallels the relative reductions in shipments
and costs presented earlier. For example, Mechanicsburg experienced the
largest percentage drops in all three measures of comparison, while
Richmond experienced the least change in all three measures. The degree
and implications of this correlation are discussed in the next chapter.

VI. ANALYTIC METHODOLOGY AND INSIGHTS

A. Motivation

The simulation experiment produced the desired output measures for each case, but was augmented by theoretical analysis for several reasons. The simulation results can be said to answer the "How Much?", but don't necessarily answer the "How?" or "Why?" questions. The more events modeled per run, the more difficult it can be to isolate key events. Inspecting different output quantities such as cost and numbers of shipments yields some clues about their relationships, but does not spell out the key effects of bank time durations. For example, why does an 18-day standard save 9.6 percent of the 15-day transportation costs, while extending the time standard another three days to 21 saved only an additional 5.4 percent (15% over the 15-day standard)?

There are inherent limits to simulation analysis. The run time for one of the 18 cases averaged 150 CPU minutes. The cases run for each depot represented only three time standards in a larger set of interest ranging from 12 to 24 days, but computer resource constraints prohibited explicitly running each alternative. Furthermore, each scenario to some degree represented an ideal depiction of the system. The output numbers may be as useful as support of general insights as they are as predictors of "real-world" performance.

General insights were sought in the form of mathematical answers to two basic questions:

> 1. What increases consolidation, and by how much? Given a certain number of shipments with one time standard, how much does this number change for a different time standard? What other factors effect consolidation?

> 2. How much money does increased consolidation save? Given a percentage change in the number of shipments, by what percentage do the total transportation charges change?

The analytic approach consisted of four steps. First, the impacts of key variables on numbers of shipments were explored to derive a useful formula for estimating numbers of shipments. Second, a transportation cost estimating formula was derived based on the number of shipments and the total weight shipped. Third, the shipment and cost results were combined to estimate transportation charges from the average cycle time. Finally, the formula parameters were derived from simulation results to estimate results for all time standards of interest.

B. Number of Shipments

1. Expected Value Results

Consider the requisitions received by a depot from customers at a single installation, or DCR, over some number of days T. Suppose that the expected number of units, or requisitions, over T is N_e and the expected total weight to be shipped is W_e. Then the average weight per unit is:

$$A_e = W_e/N_e$$

The expected number of shipments was estimated for different combinations of W_e, A_e and the number of days per cycle by making two assumptions. The first is that the unit size is a constant of size:

$$A = A_e \text{ pounds}$$

The impact of this assumption is discussed later.

Second, units were assumed to arrive at the depot according to a Poisson Process. This is equivalent to specifying that the time until the next arrival is always independent of the time since the last, or that the number of units received in a given time period is not influenced by the number received in the previous time period.

The resulting expected number of shipments is:

$$E(S) = (T/t) \sum_{k=1}^{\infty} \text{Int} \left(1 + A(k-1)/M\right) u^k e^{-u}/k!$$

where:

t = constant number of days per shipping cycle (bank time),

u = expected units per cycle

$\quad = N_e t/T$

and:

M = maximum weight per shipment.

The 'Int' function yields the largest integer less than or equal to the argument.

The above estimate can be approximated by computer because the terms in the infinite sum converge to zero, permitting estimation from a finite number of computed terms.

It should be noted that the above result minimizes the number of shipments received by the DCR. An actual DCR may experience more shipments because shipping units under ten pounds to different activities (DODAACs) will usually not be combined, and those under fifty pounds will not be combined unless the DCR has already qualified for freight. The primary benefits of consolidation appear from the simulation results to come from combining small freight into larger freight shipments; the estimate may be a fairly accurate measure of consolidation for material in this category. If one wished to estimate all categories of shipments, independent estimates for small mail shipments could be added in. The intent of the expected-value approach, however, was merely to rank certain consolidation effects.

2. Observations

The impacts of key variables on the expected number of shipments is discussed in increasing order of significance.

a. Unit Size

For a particular level of DCR total weight, the number and arrival rate of units change as the inverse of the unit size (average weight). The impact of this change is most pronounced for a DCR receiving a small total weight over a large number of cycles. There are almost as many shipments as units, because two units seldom arrive during the same cycle. The number of shipments begins to stabilize for longer cycle duration and/or more total weight, because the total expected weight per cycle becomes large enough to be relatively independent of the number of units. These relationships are illustrated by Figure 6-1a for a small-demand DCR and Figure 6-1b for a roughly normal-demand DCR.

The impact of unit size is further reduced by the fact that an increase in bank times reduces the number of shipments by about the same percentage regardless of the number of units.

b. Total Weight Received

As the total weight shipped to a DCR over a set period of time is increased, there are two points (weight levels) determining its impact on the number of shipments. The first is the point at which enough total units are received that at least one unit arrives during each cycle.

Before this level, the weight has a large impact because little consolidation is occurring; therefore, the number of shipments increases directly with the number of units. The weight value of this level is a function of unit size and cycle duration. For unit sizes between 40 and 400 pounds and cycles from two to ten days, the level is between 100,000 and 200,000 pounds per year to the DCR.

Once this first key level of DCR activity is passed, the average shipment weight increases but the expected number of shipments does not. Significant increases in shipment numbers do not begin again until a second level is reached. This is the point at which the expected weight received during a cycle exceeds the maximum shipment weight, inducing multiple shipments per cycle with regularity. The location of this point is primarily a function of cycle duration. For example, it occurred at about seven million pounds per year for a two day cycle, but at 3.5 million pounds for a four-day cycle. The relationship of weight to shipments is illustrated in Figure 6-2.

The apparent fact that a DCR's weight can increase substantially without appreciably increasing the number of shipments confirms an intuitive assumption about consolidation opportunities. Suppose two DCR's were combined into one for shipping purposes. If their combined weight is large enough but does not exceed some threshold annual amount, one could

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Figure 6-1 (a and b).   EXPECTED SHIPMENTS VS. UNIT SIZE

a.   ANNUAL PER WEIGHT 2500 POUNDS

BANK CYCLE   BANK CYCLE   BANK CYCLE

b.

BANK CYCLE   BANK CYCLE   BANK CYCLE
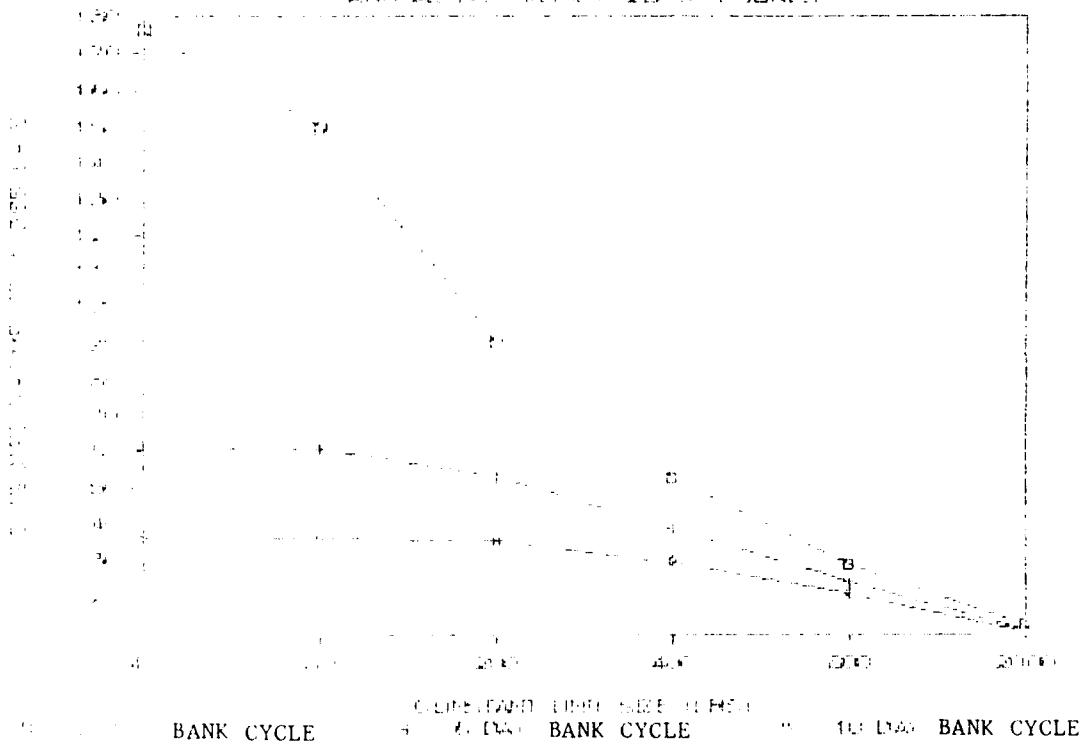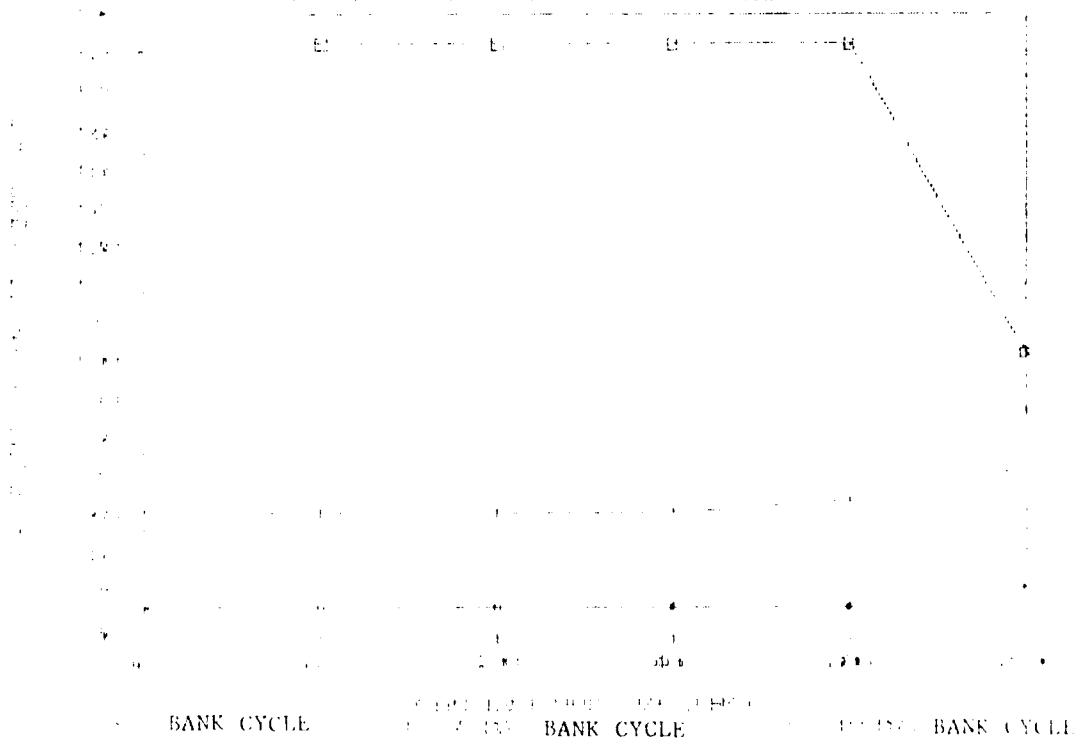
Figure 6-2.   EXPECTED SHIPMENTS VS. DCR WEIGHT
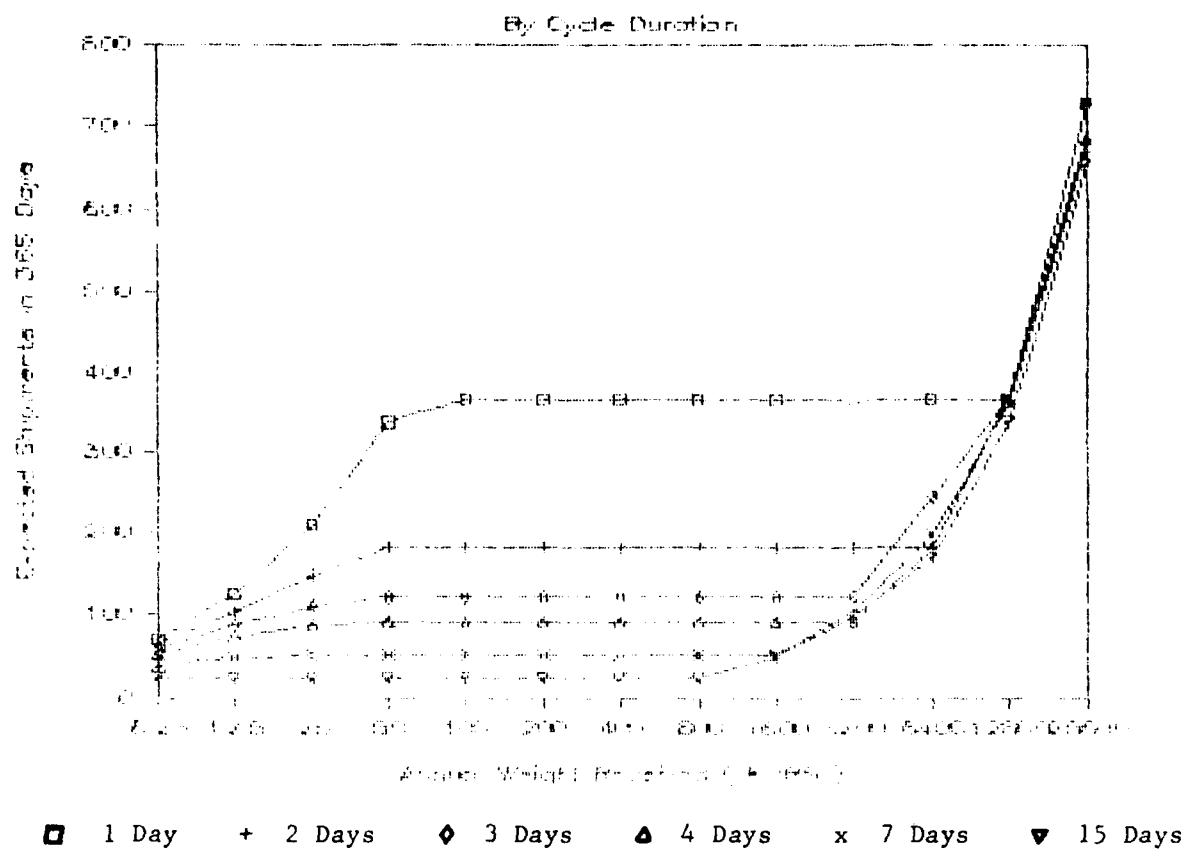
reasonably expect to reduce their total number of shipments by one-half. The purpose of this point is not to explore the feasibility or desirability of such aggregations, but rather to illustrate a general economy of scale.

c. Cycle Duration

The number of days per shipping cycle significantly impacted the number of shipments. In most cases, especially those with total weight between 100,000 and 800,000 pounds per year, there was about one shipment per cycle; at least one unit was received, but the weight per cycle seldom exceeded the maximum shipment weight. The number of shipments decreases directly as the number of cycles does, as shown in Figure 6-3a. This trend begins to disappear when sufficient weight is shipped per cycle that multiple shipments are made in each cycle, as illustrated in Figure 6-3b.

Note that increasing the cycle time does not always decrease the number of shipments. For example, when the cycle duration increased from two to three days, the number of shipments to a 6.4-million-pound-DCR increased from 183 to 243. This can be explained by noting that the average weight per cycle was 35,068 pounds for a two-day cycle, but was 52,601 for a three-day cycle. In the former, most of the 182.5 cycles experienced a single large shipment because the weight seldom exceeded 40,000 pounds; in the latter, most of the 121.7 cycles experienced a second shipment with the extra weight over the maximum truck size. The other fluctuations in the curves in Figure 6-3 are also caused by such relationships between the weight per cycle and the maximum shipment weight.

3. Time Standard

The previous section and the simulation results suggest that the single variable which was consistently correlated with the number of shipments is the number of cycles the shipped materiel is divided into. This inference was confirmed by a hypothesis test of rank correlations.

Consider the percentage change in some simulation measure of comparison from the 15-day standard to an 18-day or 21-day standard for the same depot. These changes in two measures - number of shipments and number of bank cycles - are listed for all 12 alternative cases in Table 6-1.

Figure 6-3 (a and b).   EXPECTED SHIPMENTS VS. CYCLE TIME
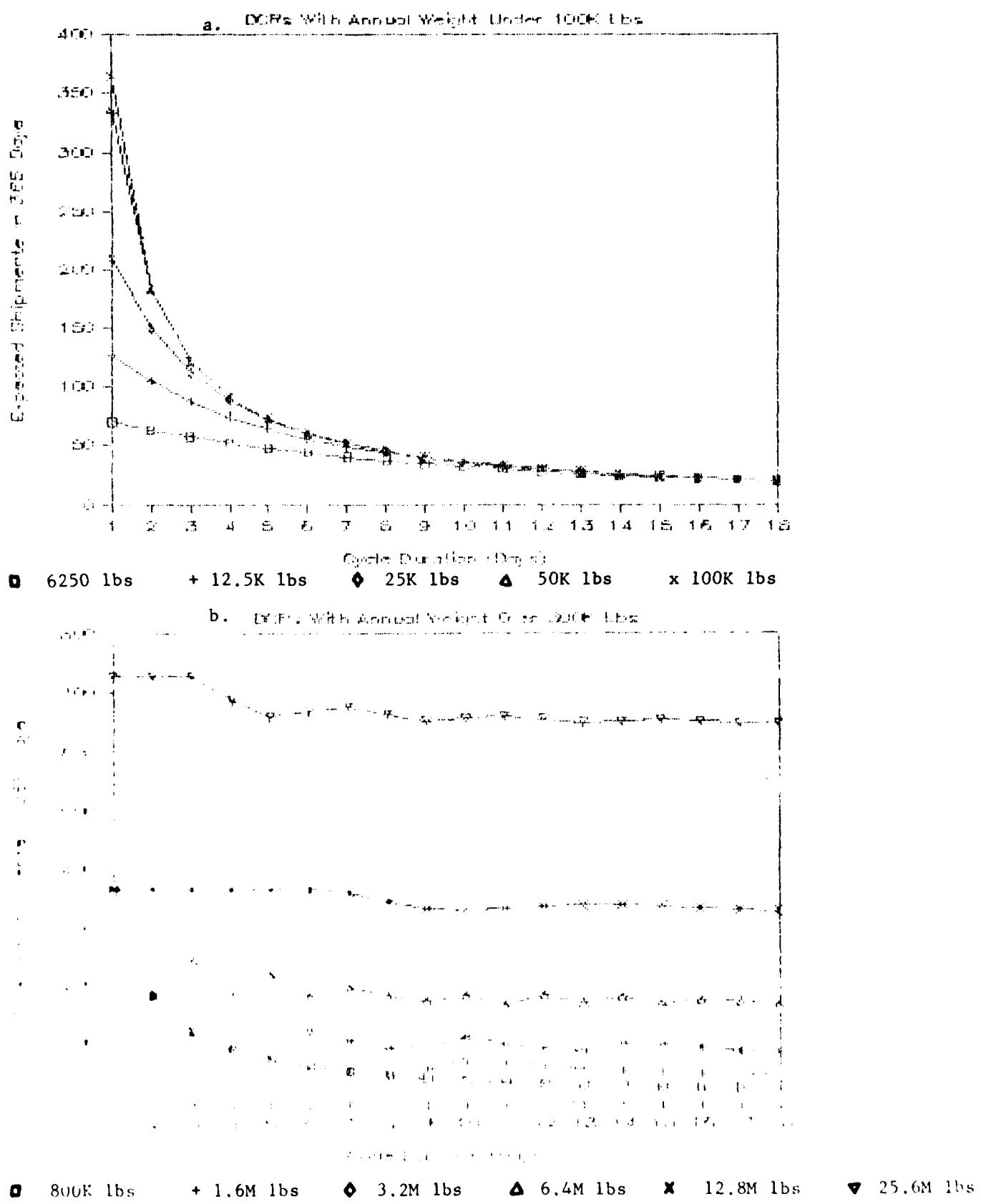
Table 6-1

ALTERNATIVE SCENARIOS RANKED BY SHIPMENT AND CYCLE REDUCTIONS

Scenario	% Shipment Reductions From 15-Day Standard	Rank	% Drop In Cycles From 15-Day Standard	Rank	Rank Difference D_i
Mech. 21	31.78	1	70.79	1	0
Ogden 21	30.17	2	68.62	2	0
Memp. 21	27.26	3	66.75	3	0
Colu. 21	27.02	4	58.21	4	0
Tracy 21	24.99	5	58.26	7	-2
Mech. 18	22.85	6	58.57	6	0
Rich. 21	19.34	7	59.07	5	2
Ogden 18	18.78	8	52.37	8	0
Memp. 18	18.35	9	51.88	9	0
Colu. 18	17.91	10	43.20	11	-1
Tracy 18	15.59	11	39.88	12	-1
Rich. 18	11.54	12	43.54	10	2

The test considered whether or not the two ranks for a scenario were related or "associated". The null and alternative hypotheses were, respectively:

H_0: There is not association between ranks;

H_1: There is a direct association between ranks.

Given the difference D_i between the two ranks for case i, i = 1,..., 12, the test statistic is Spearman's Coefficient of rank correlation.

$$R = 1 - 6\sum_{i=1}^{n} D_i^2/[n(n^2-1)]$$

$$= 1 - 6(14)/[12(143)] = .95105$$

The critical value for a one-sided test at .95 significance level for n = 12 cases is .503. That is, we reject the null hypothesis in favor of the alternate hypothesis with 95 percent confidence if R > .503. Therefore, because R = .95105, we concluded that the reductions in numbers of shipments were directly associated with the reductions in numbers of cycles. In fact, the level of significance of the test statistic was greater than .999.

The number of cycles is a direct result of the cycle duration, which is determined for each DCF by the time standard.

Let t_s be the number of days in the time standard, and t_1 be the planned combined processing and transit time for a particular DCR. Then the bank, or cycle, duration is:

$$t = t_s - t_1$$

Then the number of shipping cycles over a period of time T is:

$$c = T/t = T/t_s - t_l$$

This result reveals why one three-day increase (e.g. 15 to 18 days) in time standard results in more consolidation than another (e.g. 18 to 21 days). Let C_{15}, C_{18}, and C_{21}, be the number of cycles under the respective time standards, and let t_{15}, t_{18}, and t_{21}, be the respective bank time. If $t_l = 11$ days, then:

$$t_{15} = 15 - 11 = 4,$$

$$t_{18} = 18 - 11 = 7, \text{ and}$$

$$t_{21} = 21 - 11 = 10.$$

Then over a period T = 180 days,

$$C_{15} = 180/4 = 45 \text{ cycles,}$$

$$C_{18} = 180/7 = 25.71 \text{ cycles, and}$$

$$C_{21} = 180/10 = 18 \text{ cycles.}$$

Note that the decrease from the 15 to 18 day standard was about 19.3 cycles (42.8%) while the decrease from the 18 to 21 day standard was only 7.7 cycles (an additional 17%). This decline is in the rate of decrease in number of cycles paralleled that observed for the number of shipments. The apparent correlation motivated the form of a shipment estimating function derived from the simulation output, in a manner described in the next section.

It should be noted that the time standard increase from 15 to 18 days increased the average bank time by more than three days in the simulation results. The average bank time for all depots increased by 3.28 days from 3.47 to 6.75. Inspection of detailed results for individual areas suggested a probable cause: areas which would ideally bank for three to five days, which are common for the 15-day standard, were often dropped earlier because drops on the weekend were prohibited in the model. On the other hand, areas which ideally bank for six to eight days, which are common in the 18-day scenarios, avoided weekend problems because each cycle usually extended past the weekend regardless of the weekday it began on.

4. General Estimating Formula

A general formula was derived to estimate the number of shipments from a single variable related to the time standard. The apparent logical choice for that variable was either the total number of cycles or the overall average bank time. Bank times were more directly related to time standards, so the chosen general formula was

$$\hat{S} = S_o t^{-C}$$

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where:

$\hat{S}$ = estimated number of shipments,

t = average bank time in days,

S_o = constant parameter, and

C = constant parameter.

The simulation results for two time standards provided two equations which could be solved for the two unknowns, S_o and C. The solutions are:

$$C = \log (S_1/S_2)/\log (t_2/t_1), \text{ and}$$

$$S_o = e^{(\log S_1 + C \log t_1)},$$

where S_i and t_i are the shipments and average bank time from simulation case i.

The utility of this function was tested against the results for two depots, Richmond and Tracy. Four additional simulation cases were run - two for each depot: one for a 12-day standard and another for a 24-day standard. The 15-day and 21-day results were used to derive S_o and C and then estimates the S_i value for each of the other time standards on the basis of the simulated bank time t_i. The estimated and actual (simulation) numbers of shipments are compared in Table 6-2.

The only case with significant error was the Tracy 12-day scenario. This may be due to the sensitivity of the formula to bank times close to one. The estimating function is quite "steep" for small values of t, so small errors in t make a big difference in shipment number estimates.

<u>Table 6-2</u>

PREDICTED VS. SIMULATED SHIPMENTS

Scenario	S_o	C	t_i	No. of Shipments Simulation	No. of Shipments Predicted	% Error
Tracy						
12 days	104974	.3162	1.36	88743	95248	7.33
15 days	"	"	4.10	67194	67194	0
18 days	"	"	7.02	56720	56687	.058
21 days	"	"	10.14	50465	50465	0
24 days	"	"	13.86	45564	45717	.335
Richmond						
12 days	115672	.2331	1.72	102168	101938	.225
15 days	"	"	4.19	82880	82880	0
18 days	"	"	7.38	73318	72596	.985
21 days	"	"	10.51	66853	66853	0
24 days	"	"	13.63	62691	62923	.371

C. Total Transportation Charges

1. Approximate Shipment Cost Function

The transportation charges incurred by a depot to deliver a single shipment are primarily a function of the mode and distance of transit, the size of the shipment, and the contractual agreement with the carrier. A general cost estimating function was sought which would be reasonably accurate when applied to large numbers of shipments by all modes, depots, and customers combined. Such a function was derived from statistical analysis of shipments to the depot to its customers in a single state. The result was confirmed to be accurate for other cases, and is illustrated in Figure 6-4.

Each point plotted on this "scattergram" corresponds to one DCR; the coordinates are the natural logarithms of the total weight and total transportation charges from all the installations MROs filled by the Tracy depot over a six month period. Results for other depots are similar. The approximately linear nature of the graph supports an equation of the form

$$\log(C(x)) = \log B + a \log x,$$

where $C(x)$ is the cost of delivering a single shipment of weight x pounds. The equivalent result in non-logarithmic form leads to a function for the estimated cost $C(x)$:

$$\hat{C}(x) = Bx^a$$

where a and B are constants such that:

$$0 < a < 1, \text{ and } B > 0.$$

Note that the cost per pound, or rate $r(x)$, for the shipment is:

$$r(x) = \hat{C}(x)/x = Bx^{a-1}.$$

Consider two shipments of weight x_1 and x_2. If $x_2 > x_1$, then:

$$r(x_2)/r(x_1) = Bx_2^{a-1}/(Bx_1^{a-1})$$

$$= (x_2/x_1)^{a-1}$$

$$= (x_1/x_2)^{1-a} < 1$$

This result is less than one because $0 < 1 - a < 1$ and $0 < x_1/x_2 < 1$. Thus $r(x_2) < r(x_1)$, confirming that larger shipments tend to receive discounts in the cost per pound. Note that if $a = 1$, then the cost per pound is constant, $r(x) = B$, for any shipment.

2. Comparing Levels of Consolidation

Let $T(S,N)$ be the estimated total cost of shipping N pounds in S different shipments, and assume each shipment is of size $x = N/S$ pounds. Then:

Figure 6-4.   LOGARITHMIC SCATTERGRAM OF TRACY DCR COSTS AND WEIGHTS
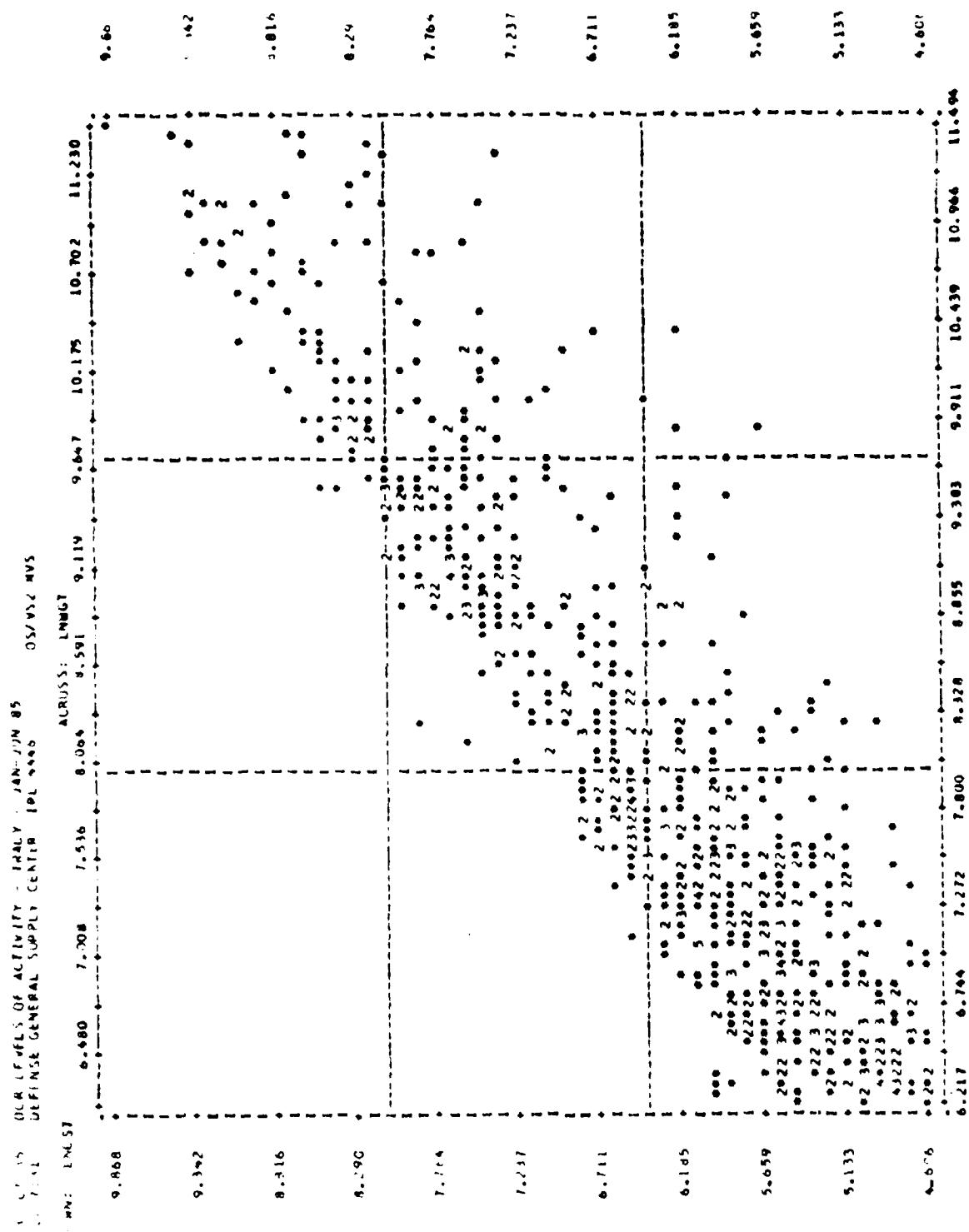
$$T(S,N) = SC(N/S) = SB(N/S)^a = BS^{1-a} N^a$$

It can be shown that assuming equal shipment sizes makes this result an upper bound for alternate forms of $T(S,N)$ based on $C(x)$.

Now consider two scenarios. In one, S_1 shipments are used; in the other, $S_2 < S_1$ are used. The ratio of the cost is:

$$R_{21} = T(S_2,N)/T(S_1,N)$$

$$= BS_2^{1-a} N^a / (BS_1^{1-a} N^a)$$

$$= (S_2/S_1)^{1-a}$$

Note that R_{21} depends only on a and the ratio S_2/S_1. For example, suppose $a = .7$ and $S_2/S_1 = .5$. Then:

$$R_{21} = (.5)^{1-.7} = (.5)^{.3} = .8123.$$

This result implies that cutting the number of shipments in half reduces the cost by $1-.8123 = .1877$, or by 18.77 percent.

3. Estimating a and B

The two cost function parameters can be estimated a number of ways. Approximate least squares techniques include linear regression of the logarithm from the cost function using a large number of actual shipments:

$$\log y = \log \hat{B} + \hat{a} \log x + E, \text{ or}$$

y = actual cost of shipment

x = weight of shipment

$\hat{B}$ = estimate of B

$\hat{a}$ = estimate of a

E = predicted minus actual cost (error of prediction)

Performing this regression for different depots yielded a values ranging from .45 to .75. The estimates for B, which affects the magnitude but not the ratio of cost estimates for different scenarios, ranged more substantially from depot to depot. This is because B can be considered the scaling parameter, while a is the shape parameter. Most actual cost functions yield about the same percentage discounts, or cost breaks, for a given increase in weight; hence they have the same shape, and we may be able to estimate a universal $\hat{a}$ for application to any or all depots. A value for $\hat{B}$ could then be derived for a particular case.

The primary purpose for estimating a and B was to generalize the simulation results and permit their extension to other scenarios. Therefore, the cost function parameters were derived, not by statistical techniques, but

directly from the simulation results. Let S_i and T_i be the total shipments and estimated cost for simulation scenario i. If scenario 1 is the combined results for the 15-day time standard and scenario 2 is the combined results for the 18-day time standard, then:

$$S_1 = 512,098, \quad T_1 = \$15,711.37K,$$

$$S_2 = 421,307, \quad T_2 = \$14,208.02K.$$

First estimate $\hat{a}$ from the ratio formula:

$$R_{21} = T_2/T_1 = (S_2/S_1)^{1-\hat{a}} \; ;$$

$$\hat{a} = 1 - \log(T_1/T_2)/\log(S_1/S_2)$$

$$= .48462.$$

This result is consistent with statistical results. Either scenario's result T_i can be used to estimate $\hat{B}$: From:

$$T(S,N) = \hat{B}S^{1-\hat{a}}N^{\hat{a}}$$

we get:

$$\hat{B} = T_i S_i^{\hat{a}-1}N^{-\hat{a}}$$

where N = total pounds shipped from all depots.

$$= 251,496,233$$

Using i = 1 (15-days)

$$\hat{B} = 1.52286$$

4. Extrapolation or Interpolation

The utility of the above results can be checked by attempting to duplicate the results of the third scenario: the 21-day standard. Knowing the number of shipments S_3 yields:

$$T_3 = \hat{B}S_3^{1-\hat{a}}N^{\hat{a}} = \$13,364.01K.$$

This result is within .056 percent of the simulation result $T_3 = \$13,356.59K$.

Thus we have a means of quickly estimating the cost of a wide range of levels of consolidation.

If we had instead used the results of scenarios 1 and 3 to estimate the results of scenario 2, we would have had slightly different parameter values:

$$\hat{a} = .48284, \text{ and}$$

$$\hat{B} = 1.53976.$$

The estimated cost in scenario 2 becomes:

$$T_2 = \$14,203.10K.$$

This result is only .035 percent off the simulation result $T_2 = \$14,208.02K$. This was slightly closer because interpolation tends to be more accurate than extrapolation, although both results are quite accurate.

D. Combined Shipment and Cost Formula

The transportation cost formula derived in the last section was

$$T(S,N) = BS^{1-a}N^a.$$

In general, the number of shipments S is an unknown for a particular scenario. The value of S was estimated previously from the average bank time t by the formula

$$\hat{S} = S_0 t^{-c}.$$

Substituting this result into the cost formula yields a new formula:

$$T = BS_0^{1-a} N^a t^{-c(1-a)}$$

$$= bt^{-d},$$

where

$$b = BS_0^{1-a} N^a, \text{ and}$$

$$d = c(1-a)$$

The appropriateness of relating the total cost to the average bank time was confirmed by another hypothesis test of rank correlations. The Spearman's Coefficient of rank correlations between the percent drops in number of cycles from the baseline case and the percent cost savings was

$$R = .86014$$

This R value is significant at better than the .999 level, confirming the direct association of bank cycle reductions and cost savings.

The values of all the key parameters could be estimated from only two simulation cases, because each of the three equations has only two unknown parameters.

E. Combined Analytic and Simulation Results

The key parameters in the equations derived to estimate the number of shipments and the transportation charges were derived from two cases. One was the 15-day totals from all six depots combined, and the other was the combined 21-day results. The outputs used are summarized in Table 6-3.

Table 6-3

CASES USED TO ESTIMATE ANALYTIC PARAMETERS

i	Time Standard	Bank Time t_i	Shipments S_i	Cost T_i
1	15 days	3.47	512,098	\$15.71137M
2	21 days	9.78	374,108	\$13.35659M

The resulting estimated number of shipments for any average bank time is

$$\hat{S} = S_0 t^{-c}$$
$$= 746581 \, t^{-.3030072}$$

The parameters were computed as follows:

$$c = \log(S_1/S_2)/\log(t_2/t_1)$$
$$= \log(512098/374108)/\log(9.78/3.47)$$
$$= .3030072, \text{ and}$$
$$S_0 = S_1 t_1{}^c$$
$$= 512098 \, (3.47)^{.3030072}$$
$$= 746581$$

The total transportation charges were estimated by

$$T = b \, t^{-d}$$
$$= 19.09352 \, t^{-.1567044}$$

The parameter computations:

$$d = \log(T_1/T_2)/\log(t_2/t_1)$$
$$= \log(15.71137/13.35659)/\log(9.78/3.47)$$
$$= .1567044,$$
$$b = T_1 t_1{}^d$$

$$= 15.71137(3.47)^{.1567044}$$

$$= 19.09352$$

These parameter values are useful only for the combined results of all six depots for the six months considered, but appropriate alternate parameters could be computed for individual depots in a similar fashion, and one could probably scale the results accurately for different periods of time.

Use of these equations for a particular scenario requires some knowledge of the expected average bank time. Overall average bank times were provided by simulation cases for the three primary time standards (15, 18 and 21 days). In addition, results for two depots for 12-day and 24-day standards were available; individual area bank times were inspected to establish educated guesses about the overall average for the six depots in both time standard cases. The resulting set of five overall average bank times was 1.3, 3.47, 6.75, 9.78 and 13.19 days for the 12, 15, 18, 21 and 24 day standards, respectively. Piecewise linear estimates were created for the remaining time standards' bank times. Then the number of shipments and total transportation charges were estimated for all integer time standards from 12 to 24 days. In addition, estimates were computed for each bank time from 1 to 13 days. These results are tabulated in Table 6-4.

Table 6-4

FINAL COMBINED RESULTS FOR SIX MONTHS

Integer Time Standards				Integer Bank Times		
TS	Bank Days	Number of Shipments	Charges	Bank Days	Number of Shipments	Charges
12	1.3	689527	18.3244	1	746581	19.0935
13	2.02	603328	17.1016	2	605149	17.1283
14	2.75	549485	16.2945	3	535187	16.0738
15	3.47	512098	15.7114	4	490510	15.3653
16	4.56	471418	15.0530	5	458442	14.8373
17	5.66	441538	14.5518	6	433802	14.4194
18	6.75	418593	14.1557	7	414006	14.0753
19	7.76	401275	13.8497	8	397589	13.7838
20	8.77	386071	13.5867	9	383649	13.5317
21	9.78	374108	13.3566	10	371595	13.3101
22	10.92	361816	13.1278	11	361017	13.1128
23	12.05	351180	12.9268	12	351623	12.9353
24	13.19	341692	12.7450	13	342197	12.7740

These results are displayed graphically in Figures 6-5 and 6-6.

Figure 6-5.   ESTIMATED TOTAL CHARGES

VS. IPG 3 TIME STANDARD

TIME STANDARD (DAYS)
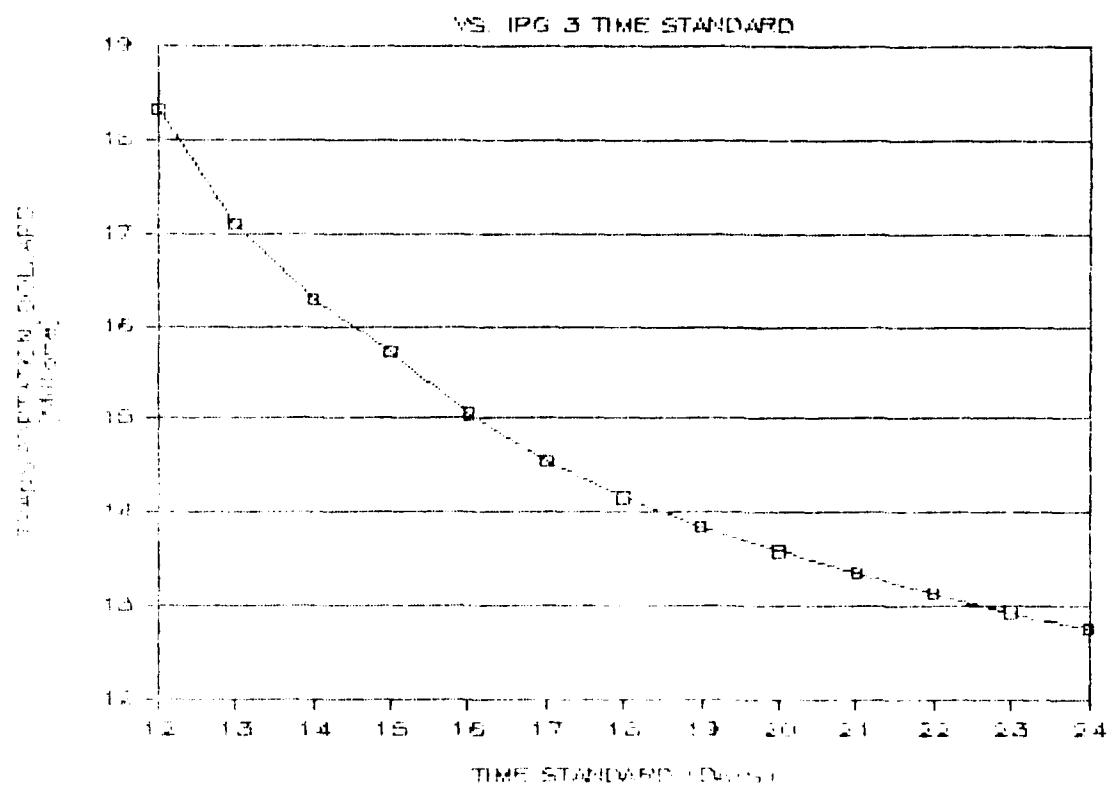
Figure 6-6.   ESTIMATED NUMBER OF SHIPMENTS

VS. IPG 3 TIME STANDARD

TIME STANDARD (DAYS)

46
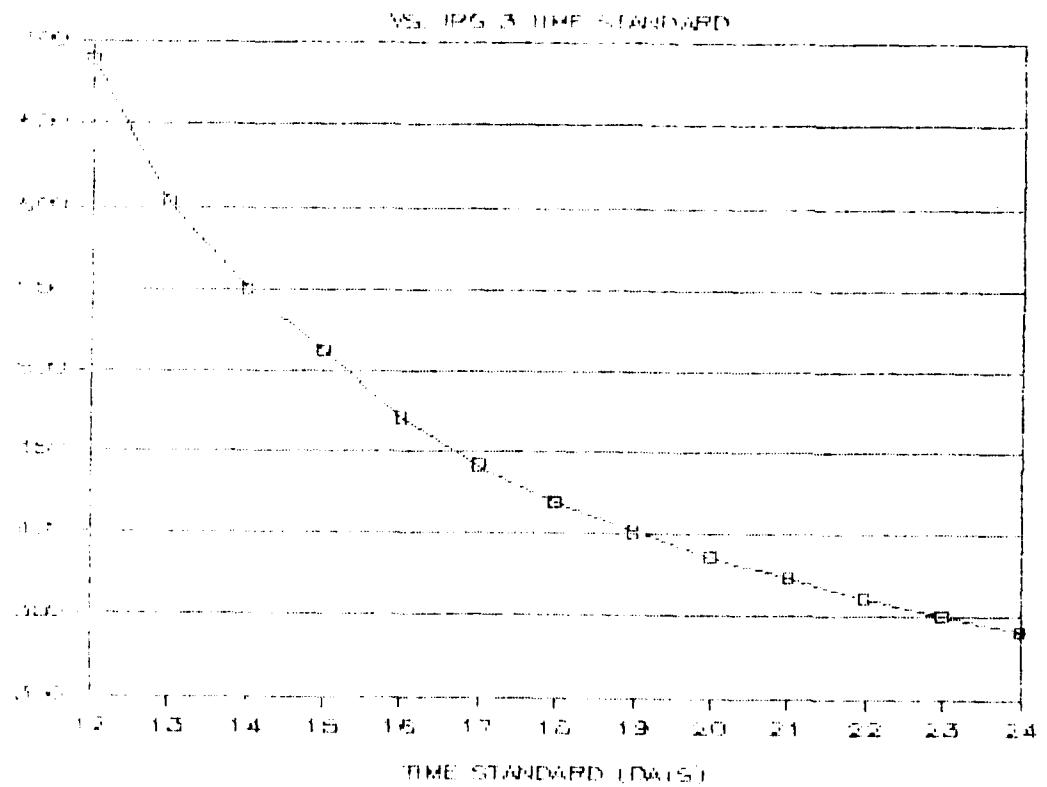
VII. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. Bank Times

MRO bank times significantly affect levels of consolidation and the resulting transportation costs.

The greatest potential benefits tend to come from extending bank times which are currently shortest.

2. An 18-Day Time Standard

Based on an extrapolation of the six month simulation results to yearly benefits, an 18-day IPG 3 time standard would reduce current transportation charges alone by over $3 million (9.6%) per year.

Shipments could be reduced by over 180,000 per year, or about 17.7 percent. Reliance on mode A (TL) shipments would increase, while both LTL and small parcel shipments would decrease substantially.

Total shipping units could be reduced at all warehouses, and at the mail and freight terminals as well. Total reductions would exceed 160,000 per year, or about 10.7%.

3. A 21-Day Time Standard

All of the estimated benefits of an 18-day time standard were exceeded by a 21-day standard, although the gains from 18 to 21 days were smaller than the gains from 15 to 18 days.

Again, based on an extrapolation of six month simulation results to yearly benefits, transportation costs would decrease by at least $4.7 million per year (about 15%).

Shipments would decrease by over 276,000 (about 27%) per year.

Total shipping units would decline by about 17.7 percent, or by over 260,000 units.

4. On-Time Performance

Increasing the time standard would make it easier to deliver materiel within the time standard. Furthermore, the increase in customer pipeline time per requisition would probably be less than half the number of days the time standard increases by. In fact, many of the supplies would probably be delivered as soon as or sooner than currently, due to increased use of fast TL shipments.

5. Other Benefits

Cost savings in several areas were not estimated, although these total savings may actually exceed those in transportation charges. Such areas to:

a. Reduced GBL costs from decreased numbers of shipments.

b. Reduced packing materials due to decreased number of shipping units.

c. Reduced numbers of drop cycles.

d. Reduced overtime due to increased bank times and resulting workload planning flexibility.

e. Reduced need for weekend processing.

6. Possible Disadvantages

At least one real consideration must be weighed against the benefits of increasing the IPG 3 time standard.

If military customers who are accustomed to certain pipeline times perceive that an increased time standard will add unacceptable delivery delays, they may upgrade many of their requisitions from IPG 3 to IPG 2. This could actually offset most or all of the cost savings, if care is not taken to maintain accurate customer perceptions of depot responsiveness.

B. Recommendations

DLA should establish the maximum IPG 3 time standard that satisfies the timeliness needs of military customers and meets other DLA objectives. If no concerns outside the scope of this analysis prohibit such a change, we recommend establishment of a 21-day standard.

DLA depots should concentrate on extending the shortest current bank times, even if the time standard is not increased. Furthermore, consolidation through bank time duration should be preferred to extending transportation hold times to gain consolidation.

Appendix A

SLAM Model Code

```
GEN,R. C. RIECKS,IPG3 TIME STANDARD,10/24/85,1,N,N,Y,N;
LIMITS,54,13,25000;
PRIORITY/1,LVF(5)/2,LVF(5)/3,LVF(5)/4,LVF(5)/5,LVF(5);
PRIORITY/6,LVF(5)/7,LVF(5)/8,LVF(5)/9,LVF(5)/10,LVF(5);
PRIORITY/11,LVF(5)/12,LVF(5)/13,LVF(5)/14,LVF(5)/15,LVF(5);
PRIORITY/16,LVF(5)/17,LVF(5)/18,LVF(5)/19,LVF(5)/20,LVF(5);
PRIORITY/21,LVF(5)/22,LVF(5)/23,LVF(5)/24,LVF(5)/25,LVF(5);
PRIORITY/27,LVF(5)/28,LVF(5)/29,LVF(5)/30,LVF(5);
PRIORITY/31,LVF(5)/32,LVF(5)/33,LVF(5)/34,LVF(5)/35,LVF(5);
PRIORITY/36,LVF(5)/37,LVF(5)/38,LVF(5)/39,LVF(5)/40,LVF(5);
PRIORITY/41,LVF(5)/42,LVF(5)/43,LVF(5)/44,LVF(5)/45,LVF(5);
PRIORITY/46,LVF(5)/47,LVF(5)/48,LVF(5)/49,LVF(5)/50,LVF(5);
PRIORITY/51,LVF(5)/26,LVF(4);
PRIORITY/53,LVF(4);
NETWORK;
   ;
   ;     EFFECT OF CHANGING DEPOT ON-TIME PERFORMANCE STANDARD
   ;
   ;     SLAM SIMULATION MODEL FOR PROJECT #5001
   ;
   ;     THIS MODEL SIMULATES A DEPOT'S MRO PROCESS, FROM RECEIPT THROUGH
   ;     'BANKING', DROPPING, WAREHOUSE PROCESSING, TRANPORTATION HANDLING
   ;     AND SHIPPING. CHOICE OF ALTERNATIVE IPG3 TIME STANDARD DETERMINES
   ;     THE BANK TIMES FOR EACH AREA'S MRO'S.
   ;
   ;     CAPT R.C.RIECKS   DLA-LO(DORO)   AV 695-4045
   ;
   ;     THE MASTER FORTRAN PROGRAM 'MAIN' IS 'GOR.RIECKS.ASM(SLAMFORT)',
   ;     AND THE JCL IS IN 'GOR.RIECKS.JCL(SLAM)'
   ;
   ;
   ;     RESOURCE TYPE 'TRK?' IS TRUCKS GOING TO AREA ? WHICH WILL BE
   ;     FREED IN EVENT SUBROUTINE 4 AND MADE AVAILABLE TO SHIPMENTS
   ;     AT 'AWAIT' NODE 53 A SET NUMBER OF DAYS AFTER THAT AREA'S MROS
   ;     ARE DROPPED.
   ;
   RESOURCE/TRKA(0),53,54/TRKB(0),53,54/TRKC(0),53,54/TRKD(0),53,54;
   RESOURCE/TRKE(0),53,54/TRKF(0),53,54/TRKG(0),53,54/TRKH(0),53,54;
   RESOURCE/TRKI(0),53,54/TRKJ(0),53,54/TRKK(0),53,54/TRKL(0),53,54;
   RESOURCE/TRKM(0),53,54/TRKN(0),53,54/TRKO(0),53,54/TRKP(0),53,54;
   RESOURCE/TRKQ(0),53,54/TRKR(0),53,54/TRKS(0),53,54/TRKT(0),53,54;
   RESOURCE/TRKU(0),53,54/TRKV(0),53,54/TRKW(0),53,54/TRKX(0),53,54;
   RESOURCE/TRKY(0),53,54;
   ;
   ;     GATE 'DRP?', INITIALLY CLOSED, WILL BE OPEN AT CERTAIN
   ;     SCHEDULED DAYS TO SIMULATE DROPS, ALLOWING ALL MROS COLLECTED
   ;     AT AWAIT NODE FOR AREA ? TO PROCEED ON TO WAREHOUSE
   ;
   GATE/DRPA,CLOSE,1,27;
   GATE/DRPB,CLOSE,2,28;
   GATE/DRPC,CLOSE,3,29;
   GATE/DRPD,CLOSE,4,30;
   GATE/DRPE,CLOSE,5,31;
   GATE/DRPF,CLOSE,6,32;
   GATE/DRPG,CLOSE,7,33;
   GATE/DRPH,CLOSE,8,34;
   GATE/DRPI,CLOSE,9,35;
   GATE/DRPJ,CLOSE,10,36;
   GATE/DRPK,CLOSE,11,37;
   GATE/DRPL,CLOSE,12,38;
   GATE/DRPM,CLOSE,13,39;
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              GATE/DRPN,CLOSE,14,40;
              GATE/DRPO,CLOSE,15,41;
              GATE/DRPP,CLOSE,16,42;
              GATE/DRPQ,CLCSE,17,43;
              GATE/DRPR,CLOSE,18,44;
              GATE/DRPS,CLCSE,19,45;
              GATE/DRPT,CLOSE,20,46;
              GATE/DRPU,CLOSE,21,47;
              GATE/DRPV,CLOSE,22,48;
              GATE/DRPW,CLOSE,23,49;
              GATE/DRPX,CLOSE,24,50;
              GATE/DRPY,CLCSE,25,51;
       ;
       ;    TIME IS IN HOURS.
       ;    CLOCK STARTS AT USER SPECIFIED DAY
       ;    MROS ARRIVED BY ACTUAL DAY RECEIVED.
       ;
       ;    EACH ENTITY IS CHARACTERIZED BY RECORD READ FROM EXTERNAL MRO FILE
       ;
       ;    GENERATE FIRST MRO LINE
       ;
FRST   CREATE;
              ACTIVITY,,,MROS;
              ACTIVITY,24.;
DAYS   EVENT,6;
              ACTIVITY,24.,,TNOW.LT.5000.,DAYS;
              ACTIVITY;
       TERM;
       ;
       ;    USE EVENT SUBROUTINE 3 TO READ RECORD FROM EXTERNAL MRO FILE,
       ;    ASSIGNING THE FOLLOWING ATTRIBUTE VALUES:
       ;       1: MARK TIME OF ENTITY (FROM CREATE NODE 'MROS')
       ;       2: GEOGRAPHICAL AREA CODE (FORMERLY A-Z, NOW 1-26)
       ;       3: SPLC GROUP (1ST 2 DIGITS)
       ;       4: DCR (DESTINATION CROSS REFERENCE CODE)
       ;       5: SHIPPING UNIT NUMBER
       ;       6: PARCEL POST ZONE
       ;       7: WEIGHT IN POUNDS
       ;       8: VOLUME IN TENTHS OF CUBIC FEET
       ;       9: BIN/BULK INDICATOR (1=BIN,2=BULK)
       ;      10: TIME TILL NEXT MRO ARRIVAL (ZERO OR MULTIPLE OF 24 HOURS)
       ;
MROS   EVENT,3;
              ACTIVITY,ATRIB(10),ATRIB(10).LT.500.,MROS;
       ;
       ;    BRANCH ACCORDING TO MRO ITEM TYPE BEFORE BRANCHING BY AREA
       ;    EACH AREA HAS TWO BANKS - ONE FOR SMALL (BIN) ITEMS AND ONE FOR
       ;    LARGE (BULK). BOTH BANKS WILL DROP AT SAME TIME ACCORDING TO
       ;    SCHEDULE CONTROLLED BY AREA'S GATE.
       ;
              ACTIVITY,,ATRIB(9).EQ.1,SMLL;
              ACTIVITY,,ATRIB(9).EQ.2,LRGE;
       ;
       ;    USE ARRIVAL OF FIRST MRO FOR EACH AREA TO ACTIVATE
       ;    DROP-SCHEDULING NETWORK
       ;
              ACTIVITY/1,USERF(1),ATRIB(2).EQ.1.AND.NNACT(1).EQ.0;
              ACTIVITY/2,USERF(1),ATRIB(2).EQ.2.AND.NNACT(2).EQ.0;
              ACTIVITY/3,USERF(1),ATRIB(2).EQ.3.AND.NNACT(3).EQ.0;
              ACTIVITY/4,USERF(1),ATRIB(2).EQ.4.AND.NNACT(4).EQ.0;
              ACTIVITY/5,USERF(1),ATRIB(2).EQ.5.AND.NNACT(5).EQ.0;
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                  ACTIVITY,,ATRIB(2).EQ.16,OPNP;
                  ACTIVITY,,ATRIB(2).EC.17,OPNQ;
                  ACTIVITY,,ATRIB(2).EQ.18,OPNR;
                  ACTIVITY,,ATRIB(2).EQ.19,OPNS;
                  ACTIVITY,,ATRIB(2).EQ.20,OPNT;
                  ACTIVITY,,ATRIB(2).EQ.21,CPNU;
                  ACTIVITY,,ATRIB(2).FQ.22,OPNV;
                  ACTIVITY,,ATRIB(2).EQ.23,OPNW;
                  ACTIVITY,,ATRIB(2).EQ.24,CPNX;
                  ACTIVITY,,ATRIB(2).EQ.25,OPNY;
     ;
     ;        OPEN AREA GATE TO ALLOW SHIPPING UNITS TO LEAVE BANK.
     ;        CLOSE AGAIN AFTER SUFFICIENT DELAY.
     ;
     OPNA   OPEN,ORPA;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSA   CLOSE,DRPA;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPNB   OPEN,DRPB;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSB   CLOSE,DRPB;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPNC   OPEN,DRPC;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSC   CLOSE,DRPC;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPND   OPEN,DRPD;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSD   CLOSE,DRPD;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPNE   OPEN,DRPE;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSE   CLOSE,DRPE;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPNF   OPEN,DRPF;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSF   CLOSE,DRPF;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPNG   OPEN,DRPG;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSG   CLOSE,DRPG;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPNH   OPEN,DRPH;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSH   CLOSE,DRPH;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPNI   OPEN,DRPI;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSI   CLOSE,DRPI;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPNJ   OPEN,DRPJ;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSJ   CLOSE,DRPJ;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPNK   OPEN,DRPK;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSK   CLOSE,DRPK;
                  ACTIVITY,ATRIB(13),,SHIP;
     OPNL   OPEN,DRPL;
                  ACTIVITY,UNFRM(.1,.9,5);
     CLSL   CLOSE,DRPL;
```

```
              ACTIVITY,ATRIB(13),,SHIP;
    OPNM  OPEN,DRPM;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSM  CLOSE,DRPM;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNN  OPEN,DRPN;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSN  CLOSE,DRPN;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNO  OPEN,DRPO;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSO  CLOSE,DRPO;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNP  OPEN,DRPP;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSP  CLOSE,DRPP;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNQ  OPEN,DRPQ;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSQ  CLOSE,DRPQ;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNR  OPEN,DRPR;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSR  CLOSE,DRPR;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNS  OPEN,DRPS;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSS  CLOSE,DRPS;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNT  OPEN,DRPT;
              ACTIVITY,UNFRM(.1,.9,5);
    CLST  CLOSE,DRPT;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNU  OPEN,DRPU;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSU  CLOSE,DRPU;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNV  OPEN,DRPV;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSV  CLOSE,DRPV;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNW  OPEN,DRPW;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSW  CLOSE,DRPW;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNX  OPEN,DRPX;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSX  CLOSE,DRPX;
              ACTIVITY,ATRIB(13),,SHIP;
    OPNY  OPEN,DRPY;
              ACTIVITY,UNFRM(.1,.9,5);
    CLSY  CLOSE,DRPY;
              ACTIVITY,ATRIB(13),,SHIP;

    ;
    ;     ATRIB(13) HOURS AFTER DROP, CALL SUBROUTINE EVENT 4 TO COMBINE
    ;     SHIPPING UNITS INTO FREIGHT UNITS AND FREE TRUCK RESOURCE(S)
    ;     FOR THIS AREA.
    ;
    SHIP  EVENT,4;
              ACTIVITY;
    TRES  ALTER,ATRIB(2)/ATRIB(10);
```

```
          ACTIVITY;
STRM  TERM;

;
;         END OF DROP-SCHEDULING NETWORK - RETURN TO MRO NETWORK
;         MROS HAVE BEEN SORTED BY SIZE. NOW BRANCH BY AREA TO BANK NODES.
;
SMLL  GCON;
          ACTIVITY,,ATRIB(2).EQ.1,DR1A;
          ACTIVITY,,ATRIB(2).EQ.2,DR1B;
          ACTIVITY,,ATRIB(2).EQ.3,DR1C;
          ACTIVITY,,ATRIB(2).EQ.4,DR1D;
          ACTIVITY,,ATRIB(2).EQ.5,DR1E;
          ACTIVITY,,ATRIB(2).EQ.6,DR1F;
          ACTIVITY,,ATRIB(2).EQ.7,DR1G;
          ACTIVITY,,ATRIB(2).EQ.8,DR1H;
          ACTIVITY,,ATRIB(2).EQ.9,DR1I;
          ACTIVITY,,ATRIB(2).EQ.10,DR1J;
          ACTIVITY,,ATRIB(2).EQ.11,DR1K;
          ACTIVITY,,ATRIB(2).EQ.12,DR1L;
          ACTIVITY,,ATRIB(2).EQ.13,DR1M;
          ACTIVITY,,ATRIB(2).EQ.14,DR1N;
          ACTIVITY,,ATRIB(2).EQ.15,DR1O;
          ACTIVITY,,ATRIB(2).EQ.16,DR1P;
          ACTIVITY,,ATRIB(2).EQ.17,DR1Q;
          ACTIVITY,,ATRIB(2).EQ.18,DR1R;
          ACTIVITY,,ATRIB(2).EQ.19,DR1S;
          ACTIVITY,,ATRIB(2).EQ.20,DR1T;
          ACTIVITY,,ATRIB(2).EQ.21,DR1U;
          ACTIVITY,,ATRIB(2).EQ.22,DR1V;
          ACTIVITY,,ATRIB(2).EQ.23,DR1W;
          ACTIVITY,,ATRIB(2).EQ.24,DR1X;
          ACTIVITY,,ATRIB(2).EQ.25,DR1Y;
LRGE  GCON;
          ACTIVITY,,ATRIB(2).EQ.1,DR2A;
          ACTIVITY,,ATRIB(2).EQ.2,DR2B;
          ACTIVITY,,ATRIB(2).EQ.3,DR2C;
          ACTIVITY,,ATRIB(2).EQ.4,DR2D;
          ACTIVITY,,ATRIB(2).EQ.5,DR2E;
          ACTIVITY,,ATRIB(2).EQ.6,DR2F;
          ACTIVITY,,ATRIB(2).EQ.7,DR2G;
          ACTIVITY,,ATRIB(2).EQ.8,DR2H;
          ACTIVITY,,ATRIB(2).EQ.9,DR2I;
          ACTIVITY,,ATRIB(2).EQ.10,DR2J;
          ACTIVITY,,ATRIB(2).EQ.11,DR2K;
          ACTIVITY,,ATRIB(2).EQ.12,DR2L;
          ACTIVITY,,ATRIB(2).EQ.13,DR2M;
          ACTIVITY,,ATRIB(2).EQ.14,DR2N;
          ACTIVITY,,ATRIB(2).EQ.15,DR2O;
          ACTIVITY,,ATRIB(2).EQ.16,DR2P;
          ACTIVITY,,ATRIB(2).EQ.17,DR2Q;
          ACTIVITY,,ATRIB(2).EQ.18,DR2R;
          ACTIVITY,,ATRIB(2).EQ.19,DR2S;
          ACTIVITY,,ATRIB(2).EQ.20,DR2T;
          ACTIVITY,,ATRIB(2).EQ.21,DR2U;
          ACTIVITY,,ATRIB(2).EQ.22,DR2V;
          ACTIVITY,,ATRIB(2).EQ.23,DR2W;
          ACTIVITY,,ATRIB(2).EQ.24,DR2X;
          ACTIVITY,,ATRIB(2).EQ.25,DR2Y;
;
;         COLLECT MROS IN BANKS - 2 FOR EACH AREA
;         DROP AS A SHIPPING UNIT REQUEST
```

```
      ;     SEND TO WAREHOUSE UPON DROP - WRHS(BIN) OR WRHL(BULK)
      ;
   DR1A  AWAIT(1),DRPA;
             ACTIVITY,,,WRHS;
   DR1B  AWAIT(2),DRPB;
             ACTIVITY,,,WRHS;
   DR1C  AWAIT(3),DRPC;
             ACTIVITY,,,WRHS;
   DR1D  AWAIT(4),DRPD;
             ACTIVITY,,,WRHS;
   DR1E  AWAIT(5),DRPE;
             ACTIVITY,,,WRHS;
   DR1F  AWAIT(6),DRPF;
             ACTIVITY,,,WRHS;
   DR1G  AWAIT(7),DRPG;
             ACTIVITY,,,WRHS;
   DR1H  AWAIT(8),DRPH;
             ACTIVITY,,,WRHS;
   DR1I  AWAIT(9),DRPI;
             ACTIVITY,,,WRHS;
   DR1J  AWAIT(10),DRPJ;
             ACTIVITY,,,WRHS;
   DR1K  AWAIT(11),DRPK;
             ACTIVITY,,,WRHS;
   DR1L  AWAIT(12),DRPL;
             ACTIVITY,,,WRHS;
   DR1M  AWAIT(13),DRPM;
             ACTIVITY,,,WRHS;
   DR1N  AWAIT(14),DRPN;
             ACTIVITY,,,WRHS;
   DR1O  AWAIT(15),DRPO;
             ACTIVITY,,,WRHS;
   DR1P  AWAIT(16),DRPP;
             ACTIVITY,,,WRHS;
   DR1Q  AWAIT(17),DRPQ;
             ACTIVITY,,,WRHS;
   DR1R  AWAIT(18),DRPR;
             ACTIVITY,,,WRHS;
   DR1S  AWAIT(19),DRPS;
             ACTIVITY,,,WRHS;
   DR1T  AWAIT(20),DRPT;
             ACTIVITY,,,WRHS;
   DR1U  AWAIT(21),DRPU;
             ACTIVITY,,,WRHS;
   DR1V  AWAIT(22),DRPV;
             ACTIVITY,,,WRHS;
   DR1W  AWAIT(23),DRPW;
             ACTIVITY,,,WRHS;
   DR1X  AWAIT(24),DRPX;
             ACTIVITY,,,WRHS;
   DR1Y  AWAIT(25),DRPY;
             ACTIVITY,,,WRHS;
   DR2A  AWAIT(27),DRPA;
             ACTIVITY,,,WRHL;
   DR2B  AWAIT(28),DRPB;
             ACTIVITY,,,WRHL;
   DR2C  AWAIT(29),DRPC;
             ACTIVITY,,,WRHL;
   DR2D  AWAIT(30),DRPD;
             ACTIVITY,,,WRHL;
   DR2E  AWAIT(31),DRPE;
```

```
                ACTIVITY,,,WRHL;
    DR2F    AWAIT(32),DRPF;
                ACTIVITY,,,WRHL;
    DR2G    AWAIT(33),DRPG;
                ACTIVITY,,,WRHL;
    DR2H    AWAIT(34),DRPH;
                ACTIVITY,,,WRHL;
    DR2I    AWAIT(35),DRPI;
                ACTIVITY,,,WRHL;
    DR2J    AWAIT(36),DRPJ;
                ACTIVITY,,,WRHL;
    DR2K    AWAIT(37),DRPK;
                ACTIVITY,,,WRHL;
    DR2L    AWAIT(38),DRPL;
                ACTIVITY,,,WRHL;
    DR2M    AWAIT(39),DRPM;
                ACTIVITY,,,WRHL;
    DR2N    AWAIT(40),DRPN;
                ACTIVITY,,,WRHL;
    DR2O    AWAIT(41),DRPO;
                ACTIVITY,,,WRHL;
    DR2P    AWAIT(42),DRPP;
                ACTIVITY,,,WRHL;
    DR2Q    AWAIT(43),DRPQ;
                ACTIVITY,,,WRHL;
    DR2R    AWAIT(44),DRPR;
                ACTIVITY,,,WRHL;
    DR2S    AWAIT(45),DRPS;
                ACTIVITY,,,WRHL;
    DR2T    AWAIT(46),DRPT;
                ACTIVITY,,,WRHL;
    DR2U    AWAIT(47),DRPU;
                ACTIVITY,,,WRHL;
    DR2V    AWAIT(48),DRPV;
                ACTIVITY,,,WRHL;
    DR2W    AWAIT(49),DRPW;
                ACTIVITY,,,WRHL;
    DR2X    AWAIT(50),DRPX;
                ACTIVITY,,,WRHL;
    DR2Y    AWAIT(51),DRPY;
                ACTIVITY,,,WRHL;
    ;
    ;       PROCESS UNIT AT SMALL-ITEM WAREHOUSE
    ;
    WRHS    QUEUE(26);
                ACTIVITY;
    WHS2    GOON;
                ACTIVITY,1.5;
    WHS3    GOON;
                ACTIVITY/26,USERF(2);
    ;
    ;       MAIL SHIPPING UNIT 10 POUNDS OR LESS BY UPS OR USPS
    ;
    SIZE    GOON;
                ACTIVITY,,ATRIB(7).LE.10,MAIL;
                ACTIVITY,,ATRIB(7).GT.10;
    ;
    ;       IF OVER 10 POUNDS, MAIL IF NO OTHER DCR SHIPPING UNIT IS
    ;       FREIGHT. SEND TO FREIGHT TERMINAL IF ONE OR MORE UNITS ARE
    ;       FREIGHT. ATRIB(10) IS THE INDICATOR VARIABLE.
    ;
```

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```
MORE    GOON;
        ACTIVITY,,ATRIB(10).EQ.0,MAIL;
        ACTIVITY,,ATRIB(10).EQ.1,FRGT;
;
;       ALL UNITS AT WAREHOUSE 2 ARE FREIGHT
;
WRH1    GOON;
        ACTIVITY,1.5;
WHL2    GOON;
        ACTIVITY/27,USERF(2);
WHL3    GOON;
        ACTIVITY/28,,ATRIB(7).LT.10000,FRGT;
        ACTIVITY/29,,ATRIB(7).GE.10000,FRGT;
MAIL    GOON;
        ACTIVITY/30;
MAL2    EVENT,5;
        ACTIVITY/32,ATRIB(13);
DSTM    COLCT,INT(1),TIME TO DELIVER,12/264./24.;
        ACTIVITY;
MTRM    TERMINATE;
FRGT    GOON;
        ACTIVITY/31;
FRT2    AWAIT(53),ATRIB(2);
        ACTIVITY/33;
FRT3    AWAIT(54),ATRIB(2);
        ACTIVITY/34,ATRIB(13);
DSTF    COLCT,INT(1),TIME TO DELIVER,12/264./24.;
        ACTIVITY;
;
FTRM    TERMINATE;
;
        END;
INIT,0,9000;
FIN;
```

JOB CONTROL CODE

```
//GOR6026A JOB (6026,OR),'RIECKS',MSGCLASS=X,CLASS=N,
//          NOTIFY=GOR6026
//HOPE    EXEC SLAMCLG,
//               REGION=4096K,
//               PARM.LKED='LET,NOLIST,NOMAP,OVLY,SIZE=(260K,60K)'
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN  DD  DSN=GOR.RIECKS.ASM(SLAMFORT),DISP=SHR
//LKED.SYSUDUMP DD  SYSOUT=*
//LKED.SYSIN  DD  DSN=DGTS.SLAM.LINKLIB(SLAMALL),DISP=SHR
//GO.SYSIN   DD  DSN=GOR.RIECKS.ASM(SLAMCODE),DISP=SHR
//GO.FTOPF001  DD DSN=GOR.R1X.MRO.A23,DISP=SHR
/*
//
```

Appendix B

SLAM Model FORTRAN Program

```
C   COMPUTE AND WRITE TOTAL UNITS
C
      NTUN(1)=0
      NTUN(2)=0
      NTUN(4)=0
      NTUN(5)=0
      DO 10 K=1,7
      NTUN(1)=NTUN(1)+CAPT(1,K)
      NTUN(2)=NTUN(2)+NLMPT(1,K)
      NTUN(4)=NTUN(4)+NPROC(1,K)
      NTUN(5)=NTUN(5)+NPROC(2,K)
10    CONTINUE
      NTUN(3)=NTUN(1)+NTUN(2)
      NTUN(6)=NTUN(4)+NTUN(5)
      IF(KDEP.EQ.1) WRITE(6,961) KSTNO
      IF(KDEP.EQ.2) WRITE(6,962) KSTNO
      IF(KDEP.EQ.3) WRITE(6,963) KSTNO
      IF(KDEP.EQ.4) WRITE(6,964) KSTNO
      IF(KDEP.EQ.5) WRITE(6,965) KSTNO
      IF(KDEP.EQ.6) WRITE(6,966) KSTNO
      WPITE(6,970) ((NCMPT(K,6),NCMPT(K,7),(NCMPT(K,J),J=1,5),NTUN(K))
     *,K=1,3)
      WRITE(6,975) ((NBEGT(K,6),NBLGT(K,7),(NBEGT(K,J),J=1,5),NTUN(K))
     *,K=1,3)
      WRITE(6,980) ((NPPGC(K,6),NPROC(K,7),(NPROC(K,J),J=1,5),
     * NTUN(K+3),K=1,3),(NTWAIT(6),NTWAIT(7),(NTWAIT(JJ),JJ=1,5)
C
C   COMPUTE TABLES' TOTALS - BOTTOM ROW(26) AND RIGHTMOST COLUMN(4)
C
      DO 20 J=1,3
      DO 15 IA=1,25
      NSHIP(26,J) = NSHIP(26,J) + NSHIP(IA,J)
      TCST(26,J) = TCST(26,J) + TCST(IA,J)
      TRTIM(26,J) = TRTIM(26,J) + TRTIM(IA,J)
15    CONTINUE
20    DO 25 IA=1,26
      NSHIP(IA,4) = NSHIP(IA,4) + NSHIP(IA,J)
      TCST(IA,4) = TCST(IA,4) + TCST(IA,J)
      TRTIM(IA,4) = TRTIM(IA,4) + TRTIM(IA,J)
25    CONTINUE
```

```
      PROGRAM MAIN
C
      DIMENSION NSSET(500000)
      COMMON/SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/ SET(500000)
      COMMON/UCOM2/ KDEP,KALL(6),NSHIP(26,4),TCST(26,4),TRTIM(26,4),
     1KSTNO,KJAYGL,NAOL(3),NCOLDF(3),KCIST(22,26),NSS(25,6),NSU(26),
     2KDIST(8,25),NCMPT(3,7),NBEGT(3,7),NPOL(3),NPROC(3,7),NTWAIT(7)
      COMMON/COM3/ MWGT(6)
      EQUIVALENCE (NSET(1),USET(1))
      NNSET = 500000
      NCRDR = 5
      NPRNT = 6
      NTAPE = 7
      CALL SLAM
      STOP
      END
```

```
      SUBROUTINE INTLC
      COMMON/SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM2/ KDEP,KALL(6),NSHIP(26,4),TCST(26,4),TRTIM(26,4),
     1KSTNO,KJAYGL,NAOL(3),NCOLDF(3),KCIST(22,26),NSS(25,6),NSU(26),
     2KDIST(8,25),NCMPT(3,7),NBEGT(3,7),NPOL(3),NPROC(3,7),NTWAIT(7)
C
C   INITIALIZE GLOBAL VARIABLES
```

B-2

```
C *** AVERAGE TRANSIT TIMES
C ***

      DO 40 J=1,6
      DO 34 IA=1,26
      DENOM=FLOAT(NSMIP(IA,J))
      IF(DENOM.LT.5) DENOM=1.
      ATTIM(IA,J)=TRTIM(IA,J)/DENOM
   34 CONTINUE
   40 CONTINUE

C *** CUMULATIVE TRANSIT TIME PROBABILITY DISTRIBUTIONS
C ***

      DO 50 IA=1,26
      DO 45 J=1,21
      KDIST(J,IA)=KDIST(J,IA)+KDIST(J-1,IA)
   45 CONTINUE
   50 CONTINUE

      DO 55 IA=1,25
      CPCL(26)=CSC(26)+NSD(IA)
      DO 55 J=1,22
      KDIST(J,26)=KDIST(J,26)+KDIST(J,IA)
   55 CONTINUE

      DO 70 IA=1,26
      DENOM=FLOAT(NSDIST(IA))
      IF(DENOM.LT.5) DENOM=1.
      DO 65 J=1,12
      JJ=J+13
      TNUM=FLOAT(KDIST(JJ,IA))
      KDIST(J,IA)=TNUM/DENOM
   65 CONTINUE
   70 CONTINUE

C *** PROVIDE BINK-TIME STATISTICS
C ***

      TTRPS=0.
      TTS=0.
      IF(KDEP.EQ.1) WRITE(6,961) KSTND
      IF(KDEP.EQ.2) WRITE(6,962) KSTND
      IF(KDEP.EQ.3) WRITE(6,963) KSTND
      IF(KDEP.EQ.4) WRITE(6,964) KSTND
      IF(KDEP.EQ.5) WRITE(6,965) KSTND
      IF(KDEP.EQ.6) WRITE(6,966) KSTND
      WRITE(6,949)
      DO IA=1,26
      TAT=0.
      L=0
      DO 75 J=1,7
      NDIST(J)=0
      CONTINUE
      DO 75 JJ=1,18
      IF(KDIST(JJ,IA).EQ.0) GOTO 75
      IF(L.GT.J) GOTO 72
      L=JJ
   72 IF(L.LT.J) GOTO 73
      NDIST(J)=L+KDIST(JJ,IA)
      NDIST(J)=NDIST(J)+KDIST(JJ,IA)
      TAT=FLOAT(JJ)+KDIST(JJ,IA))+TAT
   75 CONTINUE
```

```
      BINK=FLOAT(JJ)/IA(J)(I(J))
      IF(TTRPS.LE.0.) A=TTRPS
      IF(TTRPS.LE.0.) A=0
      TTRPS=TTURP+TTRPS
      TTAT=TTAT+TAT
      WRITE(6,990) (A,LOW,(NDDIST(J),J=1,7),ABT

   80 CONTINUE
      ABT=TTBT/TTRPS
      KTDRPS=IFIX(TTDRPS)
      MASUM=MMUL(6)
      MWGT(4)=MWGT(1)+MWGT(2)+MWGT(3)
      IF(MMGT(1).EQ.0) MW=IE1(1)=1
      DO 90 J=1,4
      CPCLB(J)=100.*TCST(126,J)/FLOAT(MWGT(J))
   90 CONTINUE

C *** WRITE OUTPUT TABLES
C ***
C ***

      WRITE(6,985) KTDRPS,ABT
      WRITE(6,948) (MWGT(M),M=1,4),MASUM
      IF(KDEP.EQ.1) WRITE(6,961) KSTND
      IF(KDEP.EQ.2) WRITE(6,962) KSTND
      IF(KDEP.EQ.3) WRITE(6,963) KSTND
      IF(KDEP.EQ.4) WRITE(6,964) KSTND
      IF(KDEP.EQ.5) WRITE(6,965) KSTND
      IF(KDEP.EQ.6) WRITE(6,966) KSTND
      WRITE(6,991) ((IA,(TCST((IA,J),J=1,4)),IA=1,26),(CPCLB(J),J=1,4)
      IF(KDEP.EQ.1) WRITE(6,961) KSTND
      IF(KDEP.EQ.2) WRITE(6,962) KSTND
      IF(KDEP.EQ.3) WRITE(6,963) KSTND
      IF(KDEP.EQ.4) WRITE(6,964) KSTND
      IF(KDEP.EQ.5) WRITE(6,965) KSTND
      IF(KDEP.EQ.6) WRITE(6,966) KSTND
      WRITE(6,992)
      IF(KDEP.EQ.1) WRITE(6,961) KSTND
      IF(KDEP.EQ.2) WRITE(6,962) KSTND
      IF(KDEP.EQ.3) WRITE(6,963) KSTND
      IF(KDEP.EQ.4) WRITE(6,964) KSTND
      IF(KDEP.EQ.5) WRITE(6,965) KSTND
      IF(KDEP.EQ.6) WRITE(6,966) KSTND
      WRITE(6,993) ((IA,(ATTIM(IA,J),J=1,4)),IA=1,26)
      IF(KDEP.EQ.1) WRITE(6,961) KSTND
      IF(KDEP.EQ.2) WRITE(6,962) KSTND
      IF(KDEP.EQ.3) WRITE(6,963) KSTND
      IF(KDEP.EQ.4) WRITE(6,964) KSTND
      IF(KDEP.EQ.5) WRITE(6,965) KSTND
      IF(KDEP.EQ.6) WRITE(6,966) KSTND
      WRITE(6,994) ((IA,(PDIST(J,IA),J=2,12)),IA=1,26)

C ***
  961 FORMAT('1','RICHMOND  ',2X,12,' DAYS'///)
  962 FORMAT('1','COLUMBUS  ',2X,12,' DAYS'///)
  963 FORMAT('1','MECHANICSBURG ',2X,12,' DAYS'///)
  964 FORMAT('1',' TRACY    ',2X,12,' DAYS'///)
  965 FORMAT('1',' OGDEN    ',2X,12,' DAYS'///)
  966 FORMAT('1',' MEMPHIS  ',2X,12,' DAYS'///)
  970 FORMAT(' SHIPPING UNIT SUMMARIES BY DAY OF WEEK'///
     1 ' UNITS COMPLETED PER DAY, BY WAREHOUSE TYPE'///' WAREHOUSE  ',
     2 ' MON   TUE   WED   THU   FRI   SAT   SUN   ALL'//
     3 '  BIN-TYPE ',7(1X,I5,1X),16/
     4 '  BULK-TYPE ',7(1X,I5,1X),16/
     5 '  COMBINED  ',7(1X,I5,1X),16)
```

```
      IF(IK.GT. ...  (AT(1),AT(1))
      ...VALUE ...  (AT(1),AT(1))
      ...VALUE ...  (AT(1),AT(1))
      DATA WTMAX/40000./,WLM1//16)CO./
    2 ...
      AALL(I)=XALL(I)+1
      GOTO (1,2,13,4,5,6),I
C ***  *****************************
C ***  ***** EVENT ROUTINE 1 *****
C ***  *****************************
C ***  COMBINE LINES INTO SHIPPING UNITS JUST BEFORE DROP FROM BANK
C ***  FOR BOTH ROOFS WHERE THE AREA'S MROS MAY BE
1     DO 170 K=1,2
      JAREA=ATIR(IR(2)+(K-1)*26
      MAX=NRQ(JAREA)
      IF(MAX.EQ.0) GOTO 170
      CALL RMOVE(1,JAREA,AT)
      NH=1
      NI=0
C ***  INITIALIZE THIS UNIT'S ATTRIBUTES
120   DO 125 J=1,8
      A(J)=AT(J)
125   CONTINUE
      A(9)=1
      A(10)=0
      IF(K.EQ.2) A(10)=1
      A(1)=AT(1)
      A(2)=AT(1)
C ***  COMBINE WITH OTHER MRO'S IF APPROPRIATE
130   IF(NR.GE.MAX) GOTO 135
      CALL RMOVE(1,JARE,AT)
      NR=NR+1
C ***  IF NEXT PSEUDO-SHIPPING-UNIT-NUMBER DOESN'T MATCH, THEN
C ***  THE ITEM IS INCOMPATIBLE OR HAS DIFFERENT DESTINATION
      IF(AT(5).NE.A(5)) GOTO 140
      KSU=IFIX(AT(5))
      M1=MOD(KSU,100)
      M2=MOD(KSU,1000)
C ***  IF THE LAST 2 DIGITS(BASED ON SPEC.REQ.CODE) ARE "00" OR
C ***  THE 3RD LAST DIGIT(BASED ON CARGO CODE) IS "0", THEN THE
C ***  ITEM CANNOT BE COMBINED, EVEN WITH LIKE ITEMS.
      IF(M1.EQ.0.OR.M2.LT.100) GOTO 140
C ***  THIS ITEM IS COMPATIBLE FOR SAME SHIPPING UNIT
      A(9)=A(9)+1
      A(7)=A(7)+AT(7)
      A(8)=A(8)+AT(8)
      IF(AT(1).LT.A(1)) A(1)=AT(1)
      IF(AT(1).GT.A(2)) A(2)=AT(1)
```

```
C ...
C ...   TOTAL DROPS = ',I5,//1X,'AVG. BANK DAYS = ',F5.2/
      ...   ',4X,'IS THE SHORTEST BANK TIME FOR GIVEN AREA')
      ...   'TOTAL WEIGHT(P 000S) SHIPPED BY MODE:',1X/
      MODE A  (1000 LBS OR MORE): ',1X/
      MODE B  (LESS THAN 1000 LBS): ',1E//
      TOTAL DROPS A (WT CONSIDERED = ',1E//
      TOTAL DROPS B ',18)
      ...   DROP CYCLE DURATIONS BY CUSTOMER AREA'///
      ...   '# CYCLES, BY DAYS DURATION',8X,'TOTAL      AVERAGE'/
      AREA      LOW      HIGH      MAX. TIME(*)/
      FORMAT(X,I2,4X,I2,6(3X,I5),7X,I5,6X,F5.2)
      ...   TRANSIT TIME SUMMARY BY MODE AND CUSTOMER AREA'///
      AREA        MODE A        MODE B        ALL'//
      25(E(1,4,41(X,F11.2))//  ALL TOTALS ARE IN DOLLARS')
      ...   NUMBER OF SHIPMENTS BY MODE AND CUSTOMER AREA'///
      AREA        MODE A        MODE B        ALL'//
      25(2X,I3,41(3X,18,1X))//
      2X,I3,4(2X,I2,1X)))
      FORMAT(' TRANSIT TIMES BY MODE AND CUSTOMER AREA'///
      AREA        MODE A        MODE B        ALL'//
      25(5,13,41(X,F11.2))//
      2X,I3,41(X,F11.2))
      ...   DISTRIBUTION OF DAYS TO CUSTOMER BY AREA'///
      AREA  <=12  <=13  <=14  <=15  <=16  <=17  <=18  <=19',
      1  <=20  <=21'
      //25(2X,I3,11(2X,F5.3))//
      2X,I3,11(2X,F5.3)))
      RETURN
      END

      SUBROUTINE EVENT(I)
      COMMON/SUM1/ ATRIH(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NLCOP,NPCNT,NNRON,NNSET,NTAPE,SSL(100),SSL(100),TNEXT,TNUM,XX(100)
     2,COMMP/SUM2/ KDEP,KALL(6),NSHIP(26,4),TCST(26,4),THTIM(26,4),
     3COST(I),NACLJ(3),NCOLO(3),KDIST(22,26),MSS(25,6),NSU(26),
     4COINT(I-25),KCMPT(3,7),NBECPT(3,7),NPOLJ(3,7),NPPROG(3,7),NTWAIT(7)
     5COM.../SUM3/ MAS(I(4)
     6SUMDI(3),TATR(I(3,15001),JATR(13,1500),NBEGG(3),NLNEM(3),NANEM(3)),
     7 NPROI(3),NPNEM(3)
```

```
      IF(AT(4).NE..M) GOTO 240
      IF(AT(7).GT.40.OR.AT(6).GT.35) NRIT=1
      GOTO 220
C ***
C *** ALL OF THIS DCR'S SU'S HAVE BEEN INSPECTED
C *** REMOVE,ALTER,AND REINSERT THOSE ENTITIES
C ***
220   NP=NP-1
      MAX=MAX-NH
      DO 250 N=1,NP
      CALL HMOVE(1,JARFA,A)
      NREM=NREM+1
      A(10)=KFRT
      A(13)=KX(.GREA+3)
      CALL FILEM(26,A)
250   CONTINUE
C ***
C *** REPEAT IF SOME MRO'S HAVE NOT BEEN PROCESSED
C ***
260   IF(MAX.GT.0) GOTO 210
      RETURN
C ***
C *** ***********************
C *** **** EVENT ROUTINE 3 *****
C *** ***********************
C *** READ EXTERNAL MRO RECORD TO ASSIGN ATTRIBUTES TO NEW ENTITY
C ***
3     IF(KALL(3).GT.1) GOTO 305
C ***
C *** THE ATTRIBUTES ARE ASSIGNED FROM THE PREVIOUS RECORD READ.
C *** THE NEW RECORD IS READ TO GET INTERARRIVAL TIME.
C *** WHICH IS PLACED IN AIR18(9).
C *** THUS TWO RECORDS ARE READ THE FIRST TIME.
C ***
      READ(8,993,END=320) (KA(K),K=1,9)
      IF(KA(2).LT.1) GOTO 3
      KJAYOL=KA(1)
      IF(KJAYOL.LT.84450) GOTO 3
      IF(KJAYOL.GT.85300) STOP
C ***
C *** DATES BEFORE 85001 MUST BE ADJUSTED TO YIELD CORRECT INTERVAL
C *** XX(1) WILL HOLD THE DATE WHEN MODEL RUN BEGINS
C ***
      IF(KJAYOL.LT.85001) KOAYOL=KOAYOL+634
      XX(3)=KJAYOL
      MMGT(4)=MMGT(4)+KA(7)
C ***
C *** ASSIGN ATTRIBUTES READ PREVIOUSLY
C ***
305   DO 310 K=2,9
      ATRIH(K)=KA(K)
310   CONTINUE
      ATRIB(1)=TNOW
      ATRIB(7)=FLOAT(KA(7))
      ATRIB(8)=FLOAT(KA(8))
      ATRIB(9)=KA(9)
C ***
C *** READ ATTRIBUTES OF SUBSEQUENT ENTITY
C ***
315   READ(8,993,END=320) (KA(K),K=1,9)
      IF(KALL(3).GT.3.AND.KA(2).LT.1) GOTO 315
```

```
C *** COMPUTE DSS PRE-ARRIVAL TIME OF CURRENT COMBINED ENTITY
C *** AND FILE THE ATTRIBUTES TO LATER INSERTION AT SAME NODE
C ***
      TIME+IA=A(1)
      TIME=A(1)
      IF(AT(4).GT..0) TIME=A(1)+135
      A(1)=TIME+IM+TIME(IM,JT)
      NIM=NIM+1
      DO 153 IA=1,12
      AT(IA)=IATR(IA,AT)
      CONTINUE
      CALL FILEM(JARFA,AT)
160   CONTINUE
170   CONTINUE
      RETURN
C ***
C *** GO BACK TO HOLD NEXT S.U. IF MORE MROS REMAIN
C *** OTHERWISE INSERT ALL S.U. ENTITIES BACK IN BANK
C ***
      IF(NREM.LE.MAX) GOTO 120
      DO 180 IA=1,A1
      DO 150 IA=1,12
      AT(IA)=IATR(IA,AT)
      CONTINUE
      CALL FILEM(JARFA,AT)
180   CONTINUE
170   CONTINUE
      RETURN
C ***
C *** *************************
C *** **** EVENT ROUTINE 2 *****
C *** *************************
C *** IF ANY FREIGHT WILL GO TO THE XCR OF S.U.'S ABOUT TO DROP.
C *** ASSIGN VALUE 1 TO ATTRIBUTE 10 OF CO-EXPANDING SU ENTITY
C ***
      JARFA=ATRIB(2)
      MAX=XX(JAREA)
      NREM=0
      IF(MAX.LE.0) GOTO 260
      CALL COPY(11,JARFA,AT)
      NQLM=FLOAT(CQCR)
      NH=1
C ***
C *** KRRT WILL BE THE 0 OR 1 INDICATOR VARIABLE
C ***
      KFRT=0
      LNQ=ANQ(JAREA+26)
      IF(LNQ.LE.0) GOTO 220
C ***
C *** LOOK FOR THIS DCR AS DESTINATION FOR S.U. IN LARGE-ITEM BANK
C ***
      MAXA=FIX(XX(11,JAREA+26+.0,XCCR,.5)
      IF(NRANK.GT.0) KFRT=1
C ***
C *** SU'S IN AREA'S AWAIT NODE ARE SEQUENCED BY DCR
C *** LOOK THROUGH ALL OF THIS DCR'S FLRE TO GO TO PRESENT
C ***
      NA=NH+1
      IF(IM.LT.MAX) GOTO 240
      LNQ=NH(JAREA)
      CALL COPY(IM,JARFA,AT)
```

```fortran
C     FINISH ATTRIBUTE ... FOR THIS SHIPMENT
440   IF(...)...
      IF(...)...
441   ...
443   MODE=2
      IF(A(7)...) MODE=1
      IS(...)=A(3)
      CALL RES...(ISUL,ISI)
      KWGT=A(7)
      A(12)=CUST
      CALL FRATF(...,KDP,KWGT,CUST,MODE)
      A(12)=CUST
      CALL TTIME(KDP,JAREA,IS,MODE,TIME)
      A(13)=24.*TIME
      A(11)=MODE
      KWGT(MODE)=KWGT(MODE)+...
C
C     UPDATE PERFORMANCE DISTRIBUTION STATISTICS
C
      KTIME=IFIX(TIME)
      DO 450 ND=1,22
      KD=ND+KTIME
      IF(KD.GT.22) KD=22
      KDIST(KD,JAREA)=KDIST(KD,JAREA)+NDIST(ND)
      NSO(JAREA)=NSO(JAREA)+NDIST(ND)
450   CONTINUE
      TRWT=A(7)/WTMAX
      TRVL=A(8)/VLMAX
      TRKS=TRWT
      IF(TRVL.GT.TRKS) TRKS=TRVL
      NTRK=IFIX(TRKS)+1
      NSHIP(JAREA,MODE)=NSHIP(JAREA,MODE)+NTRK
      TRTIM(JAREA,MODE)=TRTIM(JAREA,MODE)+TIME+FLOAT(NTRK)
      TCST(JAREA,MODE)=TCST(JAREA,MODE)+A(12)
C
C     STORE ATTRIBUTES FOR THIS SHIPMENT; GO BACK TO BEGIN ANOTHER
C
      NT=NT+1
      DO 460 IA=1,13
      TATH(IA,NT)=A(IA)
460   CONTINUE
      IF(NK.GT.0) GOTO 415
      IF(NT.EQ.0) GOTO 475
C
C     INSERT NEW SHIPMENT ENTITIES IN FREIGHT MODE
C
      DO 470 KT=1,NT
      DO 465 IA=1,13
      A(IA)=TATH(IA,KT)
465   CONTINUE
      CALL FILEM(54,A)
470   CONTINUE
C
C     KEEP NUMBER OF TRUCK RESOURCE NEEDED
```

```fortran
C     ... RETURN

C     ... MAKE TRUCK RESOURCE AVAILABLE

C     INITIALIZE ATTRIBUTES FOR THIS SHIPMENT

      DO 420 J=1,13
      A(J)=ATH(J,JAREA)
420   CONTINUE
      DO 430 K=1,22
      NDIST(K)=0
430   CONTINUE
C
C     LOOK FOR OTHER SHIPPING UNITS ELIGIBLE FOR SAME SHIPMENT
C
430   NK=NFIND(1,53,2,2,XAREA,..,5)
      IF(NK.EQ.0) GOTO 440
      CALL RMOVE(...,ATI)
      IF(TAT(4).NE.AT(1)) GOTO 460
      NDAY=IFIX((TNOW-AT(1))/24.+.5)
      IF(NDAY.GT.22) NDAY=22
      NDIST(NDAY)=NDIST(NDAY)+1
      A(9)=A(9)+AT(?)
```

B-6

```
      GOTO(...)NANE(NW)=APNEW(NW)=NPOLD(NW)
      PROG(NW)=APNEW(NW)=NPOLD(NW)
      NCMPT(NW,MDAY)=NCMPT(NW,MDAY)+NCMP(NW)
      NBEG(NW,MDAY)=NBEG(NW)+NREG(NW)
      NPROG(NW,MDAY)=NPROG(NW)+NADAY+NP+U(NW)
603   CONTINUE
      NIWAIT(MDAY)=NIWAIT(MDAY)+NWAIT
      GOTO (616,617,613,612,515,516,617),MDAY
611   WRITE(6,691) KDATE,(NCMP(IW),IW=1,3),(NBEG(IW),IW=1,3),
     *             (NPROG(IW),IW=1,3),NWAIT
      GOTO 620
612   WRITE(6,692) KDATE,(NCMP(IW),IW=1,3),(NBEG(IW),IW=1,3),
     *             (NPROG(IW),IW=1,3),NWAIT
      GOTO 620
613   WRITE(6,693) KDATE,(NCMP(IW),IW=1,3),(NBEG(IW),IW=1,3),
     *             (NPROG(IW),IW=1,3),NWAIT
      GOTO 620
614   WRITE(6,694) KDATE,(NCMP(IW),IW=1,3),(NBEG(IW),IW=1,3),
     *             (NPROG(IW),IW=1,3),NWAIT
      GOTO 620
615   WRITE(6,695) KDATE,(NCMP(IW),IW=1,3),(NBEG(IW),IW=1,3),
     *             (NPROG(IW),IW=1,3),NWAIT
      GOTO 620
616   WRITE(6,696) KDATE,(NCMP(IW),IW=1,3),(NBEG(IW),IW=1,3),
     *             (NPROG(IW),IW=1,3),NWAIT
      GOTO 620
617   WRITE(6,697) KDATE,(NCMP(IW),IW=1,3),(NBEG(IW),IW=1,3),
     *             (NPROG(IW),IW=1,3),NWAIT
      GOTO 620
620   DO 630 NW=1,3
      NCOLD(NW)=NCNEW(NW)
      NADLD(NW)=NANEW(NW)
      NPOLD(NW)=NPNEW(NW)
630   CONTINUE
691   FORMAT(2X,I5,6X,'WED.',2X,10(3X,I6))
692   FORMAT(2X,I5,6X,'THU.',2X,10(3X,I6))
693   FORMAT(2X,I5,6X,'FRI.',2X,10(3X,I6))
694   FORMAT(2X,I5,6X,'SAT.',2X,10(3X,I6))
695   FORMAT(2X,I5,6X,'SUN.',2X,10(3X,I6))
696   FORMAT(2X,I5,6X,'MON.',2X,10(3X,I6))
697   FORMAT(2X,I5,6X,'TUE.',2X,10(3X,I6))
      RETURN
C ***
      END
C ***
C ***
C ***
      FUNCTION USERF(IFN)
C ***
      COMMON/SCOM1/ ATKIB(100),ATK(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLN
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SSL(100),SSL(100),TNEXT,TNOW,XX(100
      COMMON/COM2/ KDEP,KALL(6),NSHIP(26,4),TCST(26,4),TRTIM(26,4),
     1VSTND,KDAYOL,NACLJ(3),NCOLD(3),KDIST(24,26),NSS(25,6),NSU(26),
     2KCDIST(18,25),NCMPT(3,7),ABEGT(3,7),NPOLD(3),NPROC(3,7),NWAIT(7)
C ***
      GOTO (11,2),IFA
C ***
C *** COMPUTE BANK TIME
1     KDATE=IFIX(XX(3))*TNOW/24.+.1)
      JARLA=ATK(II+2)
C ***
C *** ESTIMATE MSS IF ZERO (MISSING)
```

```
C***    TIME=ALL OF PE  ... (IM)
C***    DAY=DAILY RATE ...  ... DAY F IF IM(M-SAT,5-SUN)
        PIM=SAT+ ... ISH D, ... D... = DAY OF WEEK
        PTIM=THIA0(IZ+ ...+172 ...
        PTIM=MATE(HIT)-2.
    3   IF(PTIM=...F.PTIM) PTIM=PTIM4...
        SAY=X(3)*TY (M-24.
        KSTE=IF(K(3DAY)
        KOZ=MOD(KSTK,7)
        IF(KPO.EG.5) PTIM=PTIM+24.
        IF(KPO.EG.6) PTIM=PTIM +48.
        DFIN=SDAY*PTIM/ ...
        SP2=MOD(IF(40F(IM),7)
        IF(KPO.LT.4.AND.KDO2.GE.4) PTIM=PTIM+48.
        SLIF=PTIM
        RETURN
        END

C***
        SUBROUTINE MRATE(IZ,IWT,COST)
C***
C-AL*H  COST
    DIMENSION RPP(8,8),FDPS(8),FBAS(8),FMIN(8)
    DATA RPP/2.51,2.72,3.00,3.21,3.42,3.62,3.81,4.01,
    *   2.51,2.77,3.00,3.21,3.42,3.62,3.81,4.01,
    *   2.93,3.15,3.34,3.90,4.04,4.27,4.49,4.71,
    *   3.36,3.73,4.41,4.94,4.87,5.14,5.39,5.64,
    *   4.25,4.73,5.14,5.46,5.51,6.62,7.13,
    *   5.26,5.59,6.49,7.27,7.46,9.09,8.49,9.18,
    *   6.42,7.09,7.75,8.45,9.26,9.72,10.36,11.46,
    *   8.45,9.55,10.40,11.13,12.07,13.08,13.64,14.15/,
    *   FDPS/.0822,.0825,...126,.169,.214,.278,.345,.416/,
    *   FBA./.075,.075,.13,.175,.13,.13,1.10,1.16,1.32,1.32/,
    *   FMIN/1.23,1.23,1.32,1.46,1.52,1.55,1.67,1.74/

C***
        IF (IWT.LE.0) IWT = 1
        IW = 15
        J = 1
        IF (IWT.LT.20) GOTO 20
        IW = 20
        J = 2
        IF (IWT.LT.25) GOTO 20
        IW = 25
        J = 3
        IF (IWT.LT.30) GOTO 20
        IW = 30
        J = 4
        IF (IWT.LT.35) GOTO 20
        IW = 35
        J = 5
        IF (IWT.LT.40) GOTO 20
        IW = 40
        J = 6
        IF (IWT.LT.45) GOTO 20
        IW = 45
        J = 7
    20  CONTINUE
        CPP = RPP(J,IZ)+(RPP(J+1,IZ)-RPP(J,IZ))*(FLOAT(IWT-IW)/5.
        CDPS = AMAX1(FMIN(IZ),FBAS(IZ) + FDPS(IZ)*(FLOAT(IWT)))
        COST = AMIN1(CPP,CDPS)
        RETURN
        END
```

```
C***   ... ... ...
C***   ... ...
C***
C***   ... ... ... RIPPED
C***   ... ... ...
C***
C***   ... ... RPS(1,11 ...,JAREA+,KPP)=1+1
       ...
       ... ...
C***   ... ... ...   AND SUMMIED PLANNED.
C***   ... ... DAY OF SHIP+ MUST BEGIN
C***   ... ...
       ... ...
C***   ... ... THURSDAY AND FRIDAY SHIP+5
       ...
       ...
C***   SATURDAY ADDS TO FRIDAY AND BEGIN PROCESSING TUESDAY
       IF(KO ...) GOTO 3.
       IF(KO .EG.3) M-F=MTJ-1

C***   MOVE SUNDAY MT2IS TO MONDAY AND BEGIN PROCESSING WEDNESDAY
       ...
C***   COMPUTE THE REQUIRED BANK TIME; AT LEAST ONE DAY
       J-T=FL AF(MOT)-P-TM
       IF(KOT.GE.1.0 ... 12
       KOT=1.
       PRIM=FLOAT(MOT)-OUT
       IF(KOT.LT.1.OR.KOT.GT.141 STOP
       .0015,KOST,JRS,N=KBISK(KOF,JAREA1+:
C***   COMPUTE AND SAVE PLANNED PROCESS TIME TO SCHEDULE TRUCK
       K=1IF1+(COST)
       XT(JAREA3) = 2.+RPTIM+2.
       N-TJ=N.
C***   COMPUTE TIME TILL PROCESSING DONE
       ...
```

Appendix C

Sample Simulation Output Case

TRACY   15 DAYS

SHIPPING UNIT SUMMARIES BY DAY OF WEEK

UNITS COMPLETED PER DAY, BY WAREHOUSE TYPE

WAREHOUSE	MON	TUE	WED	THU	FRI	SAT	SUN	ALL
BIN-TYPE	21503	17389	22301	12959	4178	0	0	78329
BULK-TYPE	6028	5186	6917	3917	125C	0	0	23298
COMBINED	27531	22575	29218	16875	5428	0	0	1C1627

UNITS DROPPED EACH DAY, BY WAREHOUSE TYPE

WAREHOUSE	MON	TUE	WED	THU	FRI	SAT	SUN	ALL
BIN-TYPE	6080	33373	3963	90	34823	0	0	78329
BULK-TYPE	2518	9613	1644	44	9479	0	0	23298
COMBINED	8598	42986	5607	134	443C2	0	0	101627

UNITS PREPARED EACH DAY, BY TRANSIT TYPE

UNIT TYPE	MON	TUE	WED	THU	FRI	SAT	SUN	ALL
MAIL ITEM	15523	11856	15647	8926	2820	0	0	54772
FREIGHT	12008	10719	13571	7949	2608	0	0	46855
COMBINED	27531	22575	29218	16875	5428	0	0	1C1627

UNITS HELD OVER AT FREIGHT TERMINAL AT END OF DAY

MON	TUE	WED	THU	FRI	SAT	SUN
13548	24193	17391	20058	4881	4881	4881

TRACY   15 DAYS

DROP CYCLE DURATIONS BY CUSTOMER AREA

AREA	"LOW"	NUM. OF CYCLES, BY DAYS DURATION						TOTAL DROPS	AVERAGE BANK TIME
		LOW	LOW+1	LOW+2	LOW+3	LOW+4	LOW+5		
1	4	9	9	17	0	0	0	35	5.23
2	4	9	9	18	0	0	0	36	5.25
3	4	9	9	18	0	0	0	36	5.25
4	4	9	8	15	0	0	0	36	5.28
5	4	10	9	19	0	0	0	38	5.24
6	4	9	9	18	0	0	0	36	5.25
7	4	10	9	18	0	0	0	37	5.22
8	3	27	26	1	0	0	0	54	3.52
9	4	10	9	18	0	0	0	37	5.22
10	3	26	24	3	0	0	0	53	3.57
11	3	26	25	3	0	0	0	54	3.57
12	4	10	8	19	0	0	0	37	5.24
13	3	27	27	0	0	0	0	54	3.50
14	3	27	25	2	0	0	0	54	3.54
15	4	9	9	19	0	0	0	37	5.27
16	3	26	25	2	0	0	0	53	3.55
17	3	26	26	1	0	0	0	53	3.53
18	3	28	26	1	0	0	0	55	3.51
19	3	27	26	1	0	0	0	54	3.52
20	3	27	26	1	0	0	0	54	3.52
21	3	27	26	1	0	0	0	54	3.52
22	3	26	25	2	0	0	0	53	3.55
23	3	27	27	0	0	0	0	54	3.50
24	5	2	4	2	0	0	0	8	6.00
25	3	27	25	2	0	0	0	54	3.54

TOTAL DROPS = 1126

AVG. BANK DAYS = 6.10

"LOW" IS THE SHORTEST BANK TIME FOR GIVEN AREA

```
TOTAL WEIGHT(POUNDS) SHIPPED BY MODE:
   MODE A (10000 LBS OR MORE) : 23736846
   MODE B (LTL - < 10000 LBS) : 11046778
   MODES G OR 5 (UPS OR USPS) :   508138

TOTAL IP33 WEIGHT CONSIDERED : 35291762

TOTAL READ IN : 35291762
```

TRACY   15 DAYS

TRANSF. COST SUMMARY BY MODE AND CUSTOMER AREA

AREA	MODE A	MODE B	MODE C/S	ALL
1	4437.76	6848.91	852.45	12139.12
2	21159.02	30660.80	3344.29	55164.11
3	18716.04	19935.42	2135.45	40786.91
4	15837.63	8704.15	845.96	25387.74
5	25867.00	46248.01	5809.75	77924.75
6	17472.86	18477.29	2336.08	38286.23
7	26633.50	11862.03	432.24	38927.77
8	20054.36	81507.81	5916.30	107478.38
9	32222.04	4763.14	1193.72	38178.89
10	11097.36	62725.76	11513.52	85336.63
11	51322.16	56696.98	9244.52	117263.63
12	69787.00	29301.75	2750.00	101838.69
13	17822.97	19577.67	196.82	37597.46
14	12501.54	79865.00	13495.13	105861.63
15	63485.66	27190.99	3104.77	93781.38
16	3919.53	53632.37	9748.94	73300.81
17	0.0	23912.79	5708.93	29621.72
18	27181.20	238705.44	24825.42	290712.00
19	2837.85	54366.26	7331.27	64535.38
20	0.0	38991.67	9877.05	48868.72
21	1317.43	68199.75	16351.03	85868.13
22	6077.24	143643.44	20745.47	170466.06
23	68446.50	119550.88	16397.36	204394.69
24	0.0	50.00	39.25	89.25
25	100162.31	69919.44	7711.21	177792.94
26	618358.44	1321335.00	181906.63	2121599.00
$/CNT:	2.61	11.96	35.80	6.01

ALL TOTALS ARE IN DOLLARS

Area No. 26 is the total or overall results on this and subsequent tables.

TRACY   15 DAYS

NUMBER OF SHIPMENTS BY MODE AND CUSTOMER AREA

AREA	MODE A	MODE B	MODE G/S	ALL
1	12	112	403	527
2	70	538	1691	2299
3	82	370	1038	1490
4	41	106	377	524
5	79	660	2311	3050
6	50	302	840	1192
7	79	75	293	447
8	30	657	2074	2761
9	84	32	845	961
10	15	738	4236	4989
11	77	764	3743	4584
12	208	239	1424	1871
13	31	79	101	211
14	17	731	4384	5132
15	70	216	1274	1560
16	4	521	2959	3484
17	0	245	1537	1782
18	29	1418	5546	6993
19	2	477	1804	2283
20	0	355	2044	2399
21	1	650	3727	4378
22	5	982	4278	5265
23	42	675	4171	4888
24	0	2	10	12
25	137	313	3662	4112
26	1165	11257	54772	67194

TRACY   15 DAYS

TRANSIT TIMES BY MODE AND CUSTOMER AREA

AREA	MODE A	MODE B	MODE G/S	ALL
1	3.57	5.03	4.86	4.87
2	3.50	4.71	4.80	4.74
3	3.64	4.78	4.61	4.60
4	2.79	4.95	4.73	4.62
5	3.41	4.72	4.70	4.67
6	3.38	4.89	4.76	4.74
7	3.49	4.44	4.69	4.44
8	3.85	5.75	5.82	5.78
9	3.90	4.80	4.70	4.63
10	4.56	6.50	6.53	6.52
11	4.14	5.90	6.00	5.95
12	3.24	4.71	4.68	4.52
13	3.44	5.32	5.47	5.12
14	4.57	6.77	6.78	6.77
15	4.01	5.91	5.91	5.82
16	4.59	6.79	6.77	6.77
17	0.0	6.73	6.81	6.80
18	4.54	6.79	6.80	6.79
19	4.27	6.82	6.79	6.79
20	0.0	6.83	6.81	6.81
21	4.45	6.72	6.73	6.73
22	4.62	6.76	6.80	6.79
23	4.44	6.80	6.80	6.78
24	0.0	4.15	5.06	4.91
25	3.91	5.68	6.04	5.94
26	3.69	6.15	6.25	6.19

DAY: 10 DAYS

DISTRIBUTION OF DAYS TO CUSTOMER BY AREA

AREA	<=12	<=13	<=14	<=15	<=16	<=17	<=18	<=19	<=20	<=21	>21
1	0.700	0.709	0.945	0.986	0.957	0.995	1.000	1.000	1.000	1.000	0.0
2	0.707	0.870	0.946	0.984	0.997	1.000	1.000	1.000	1.000	1.000	0.0
3	0.755	0.863	0.940	0.977	0.995	1.000	1.000	1.000	1.000	1.000	0.0
4	0.787	0.878	0.952	0.982	0.992	0.996	1.000	1.000	1.000	1.000	0.0
5	0.772	0.878	0.949	0.979	0.995	0.999	1.000	1.000	1.000	1.000	0.0
6	0.741	0.852	0.924	0.975	0.951	0.997	1.000	1.000	1.000	1.000	0.0
7	0.625	0.939	0.980	0.996	0.958	1.000	1.000	1.000	1.000	1.000	0.0
8	0.650	0.886	0.922	0.965	0.991	0.998	1.000	1.000	1.000	1.000	0.0
9	0.327	0.825	0.969	0.993	0.999	1.000	1.000	1.000	1.000	1.000	0.0
10	0.611	0.833	0.963	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.0
11	0.677	0.837	0.940	0.980	0.954	0.999	1.000	1.000	1.000	1.000	0.0
12	0.700	0.903	0.961	0.986	0.995	0.997	1.000	1.000	1.000	1.000	0.0
13	0.815	0.904	0.948	0.978	0.988	0.999	1.000	1.000	1.000	1.000	0.0
14	0.573	0.826	0.969	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.0
15	0.629	0.827	0.951	0.993	1.000	1.000	1.000	1.000	1.000	1.000	0.0
16	0.558	0.826	0.963	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.0
17	0.584	0.845	0.966	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.0
18	0.549	0.831	0.965	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.0
19	0.547	0.611	0.964	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.0
20	0.587	0.829	0.974	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.0
21	0.594	0.845	0.968	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.0
22	0.554	0.828	0.968	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.0
23	0.570	0.826	0.967	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.0
24	0.333	0.750	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.0
25	0.806	0.923	0.976	0.994	0.999	1.000	1.000	1.000	1.000	1.000	0.0
26	0.660	0.854	0.960	0.992	0.998	1.000	1.000	1.000	1.000	1.000	0.0

DAY JUST ENDED	DAY OF WEEK	SHIP. UNITS COMPLETED FIN	BULK	TOTAL	# STARTED ON THIS DAY FIN	BULK	TOTAL	TYPE OF SHIP. UNIT MAIL	FREIGHT	TOTAL	# LEFT IN TRAN.HOLD
84985	SUN.	0	0	0	0	0	0	0	0	0	0
84986	MON.	0	0	0	0	0	0	0	0	0	0
84987	TUE.	0	0	0	0	0	0	0	0	0	0
84988	WED.	0	8	8	6	8	14	0	8	8	8
84989	THU.	5	0	5	0	0	0	5	0	5	8
84990	FRI.	1	0	1	4	3	7	0	1	1	9
84991	SAT.	0	0	0	0	0	0	0	0	0	9
84992	SUN.	0	0	0	0	0	0	0	0	0	9
84993	MON.	8	4	12	30	13	43	8	4	12	4
84994	TUE.	19	10	29	27	20	47	17	12	29	16
84995	WED.	28	17	45	23	11	34	26	19	45	32
84996	THU.	20	12	32	2	0	2	15	17	32	34
84997	FRI.	17	5	22	38	28	66	12	10	22	21
84998	SAT.	0	0	0	0	0	0	0	0	0	21
84999	SUN.	0	0	0	0	0	0	0	0	0	21
85000	MON.	43	31	74	316	103	419	36	38	74	40
85001	TUE.	243	91	334	601	252	853	163	171	334	211
85002	WED.	467	166	633	25	6	31	333	300	633	467
85003	THU.	218	101	319	88	44	132	148	171	319	426
85004	FRI.	106	44	150	409	149	558	80	70	150	82
85005	SAT.	0	0	0	0	0	0	0	0	0	82
85006	SUN.	0	0	0	0	0	0	0	0	0	82
85007	MON.	284	114	398	368	159	527	222	176	398	246
85008	TUE.	454	159	613	1022	257	1279	309	304	613	476
85009	WED.	737	211	948	77	35	112	572	376	948	607
85010	THU.	363	102	465	0	0	0	259	206	465	510
85011	FRI.	150	45	195	1616	508	2124	112	83	195	129
85012	SAT.	0	0	0	0	0	0	0	0	0	129
85013	SUN.	0	0	0	0	0	0	0	0	0	129
85014	MON.	994	312	1306	83	37	120	681	625	1306	692
85015	TUE.	641	217	858	1197	354	1551	411	447	858	1139
85016	WED.	768	234	1002	286	131	417	542	460	1002	507
85017	THU.	564	197	761	0	0	0	368	393	761	826
85018	FRI.	221	75	296	1492	432	1924	144	152	296	338
85019	SAT.	0	0	0	0	0	0	0	0	0	338
85020	SUN.	0	0	0	0	0	0	0	0	0	338
85021	MON.	884	257	1141	125	61	186	647	494	1141	565
85022	TUE.	688	225	913	1576	522	2098	482	431	913	996
85023	WED.	980	331	1311	53	13	66	643	668	1311	735
85024	THU.	542	173	715	0	0	0	364	351	715	1015
85025	FRI.	143	42	185	1282	398	1680	96	89	185	103
85026	SAT.	0	0	0	0	0	0	0	0	0	103
85027	SUN.	0	0	0	0	0	0	0	0	0	103
85028	MON.	809	268	1077	435	192	627	567	510	1077	589
85029	TUE.	744	270	1014	1256	364	1620	480	534	1014	1123
85030	WED.	900	269	1169	91	36	127	636	533	1169	805
85031	THU.	456	132	588	0	0	0	313	275	588	684
85032	FRI.	137	41	178	1304	431	1735	97	81	178	135
85033	SAT.	0	0	0	0	0	0	0	0	0	135
⋮	⋮										
85175	MON.	773	213	986	372	172	544	514	472	986	522
85176	TUE.	720	244	964	1059	203	1262	481	483	964	1035
85177	WED.	730	174	904	74	31	105	533	371	904	626
85178	THU.	407	86	493	0	0	0	286	207	493	480
85179	FRI.	126	23	149	1313	203	1516	88	61	149	106
85180	SAT.	0	0	0	0	0	0	0	0	0	106
85181	SUN.	0	0	0	0	0	0	0	0	0	106
85182	MON.	780	121	901	90	9	99	592	309	901	347
85183	TUE.	495	80	575	62	10	72	381	194	575	541
85184	WED.	73	8	81	0	0	0	56	25	81	47
85185	THU.	14	2	16	0	0	0	8	8	16	27
85186	FRI.	0	0	0	0	0	0	0	0	0	0
85187	SAT.	0	0	0	0	0	0	0	0	0	0
85188	SUN.	0	0	0	0	0	0	0	0	0	0
85189	MON.	0	0	0	0	0	0	0	0	0	0
85190	TUE.	0	0	0	0	0	0	0	0	0	0
85191	WED.	0	0	0	0	0	0	0	0	0	0
85192	THU.	0	0	0	0	0	0	0	0	0	0

END

FILMED

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DTIC